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THE TILBURY DEEP-WATER DOCKS.

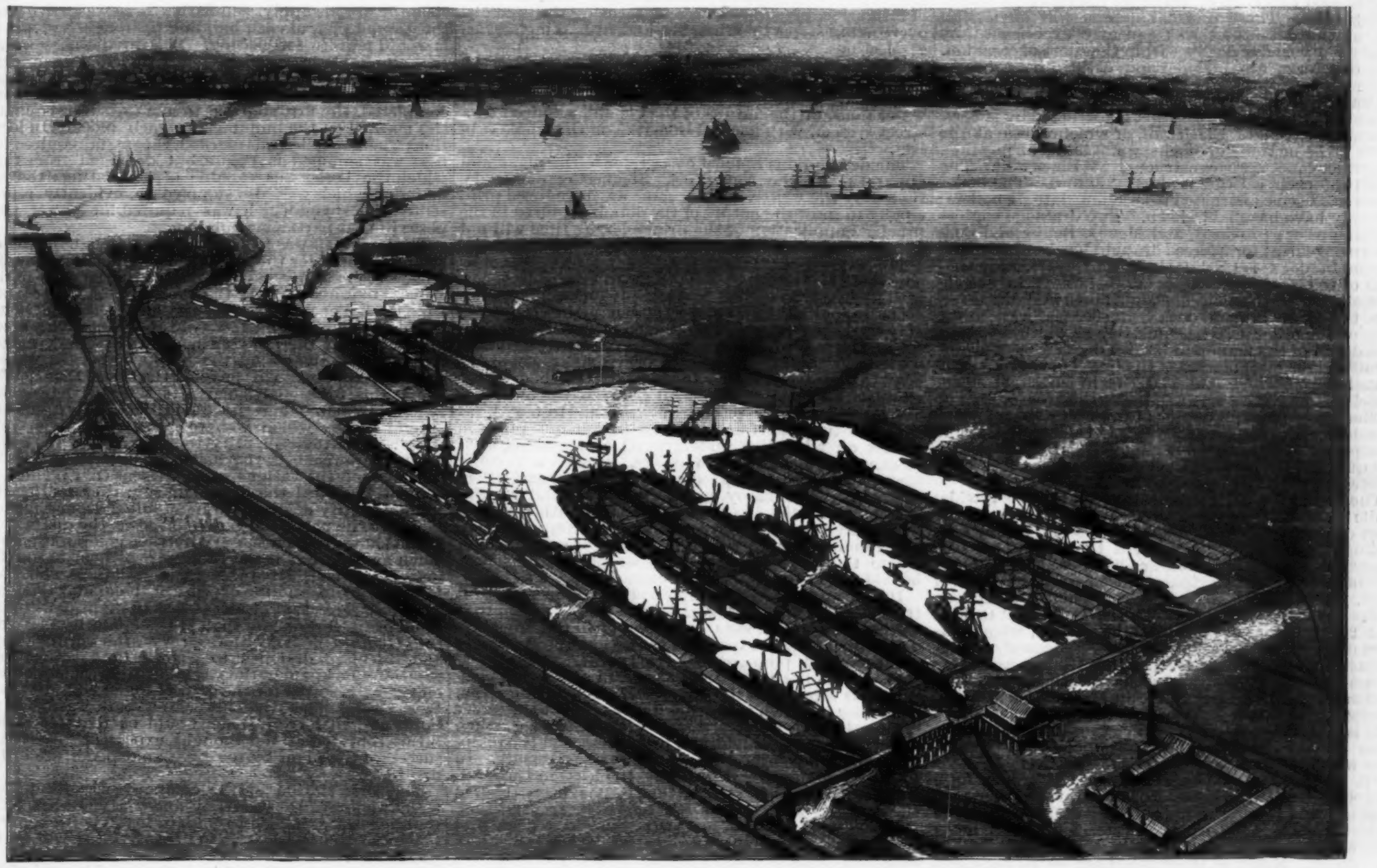
THE opening of the new deep-water docks at Tilbury on April 16 is an event which must have a great and almost incalculable influence on the trade of London. The enterprise, which has been undertaken by the East and West India Dock Company, has involved an expenditure of about fifteen millions of dollars, and the whole work, since the passing of the Act of Parliament by the authority of which it has been achieved, has occupied less than four years. The real commencement of operations only dates from October 27, 1884, when the undertaking was taken over by Messrs. Lucas and Aird from the previous contractors, and the total quantities of the principal works carried out from October 27, 1884, to April 17, 1886, were as follows: Excavation, 3,275,000 cubic yards; concrete, 640,000 cubic yards; brickwork, 46,000 cubic yards; masonry, 260,000 cubic feet; shedding, 20 acres; permanent road laid, 22 miles. The materials used consisted of the following items: Ballast, 700,000 cubic yards; bricks, 19 millions; cement, 65,000 tons; stone, 260,000 cubic feet; slating, 1,056,000 square feet; ironwork, 4,100 tons; galvanized sheeting, 300,000 square feet; timber, balk, 1,530,000 cubic feet; ditto, planks and boarding, 13,200,000 linear feet; coal and coke, 40,500 tons; and the machinery and plant were: locomotives, 54; portable engines, 35; pumping engines, 46; steam cranes, pile engines, etc., 207; steam excavators, 6; dredgers, 5; total engines in steam, 250; wagons, 1,650; rails, 4,000 tons; sleepers, 76,000; temporary road laid, 38 miles; timber, 2,000,000 cubic feet; horses, 80. The average number of men employed was 4,500, and the water pumped was (*maximum* quantity) 13,000 gallons per minute.

But what end do these docks, some 30 miles down the Thames, subserve, and what is the justification of this immense outlay of labor and money? The answer is, the enormous saving of time and money which is effected if ships can be docked and goods transshipped at Tilbury instead of having to proceed to the docks in the port of London itself. Big steamers come up the river till they come to Gravesend, where the tide ceases to serve them. They then have to wait six hours or more till the tide serves them again. Thus, by the erection of these docks, each way a delay of from six to twelve hours is obviated. In addition to this the charges for towage and pilotage are saved, these charges in the case of large steamers amounting sometimes to as much as £60 each way. Then all the risks of collision and of shoals are avoided, and in the case of passenger steamers the owners effect a considerable economy of stores and provisions. It should also be mentioned that in respect of freights no additional cost is incurred by ships unloading and docking at Tilbury instead of proceeding up the river, and that it has sometimes happened that vessels have had to make two fruitless voyages from Gravesend to the docks and back again in consequence of there being no room for them in the docks.

The principal works consist of a tidal basin and main and branch docks. The tidal basin, with a water area of 19 acres, has at low-water spring tides a depth of 26 feet, while at ordinary high-water springs the depth is 45 feet, thus enabling the largest steamships to enter and leave irrespective of conditions of tide. In the basin there are two arrival and departure quays (each 600 feet long) for discharging and loading at all states of the tide. The northwestern quay of the basin, named the transshipment quay, is over 300 feet in length, and is chiefly intended for transshipments to and from Continental steamers. The coaling jetty at the southwestern quay of the tidal basin is fitted with four 30 cwt. movable hydraulic cranes, with weighing apparatus, constructed by Sir W. G. Armstrong, Mitchell, and Co. (Limited), of Newcastle on Tyne, for discharging coal from steam colliers into barges, and, by means of bridges connecting the jetty with the land, coals can also be tipped into railway trucks.

On the south quay of the tidal basin a shed has been erected for the accommodation of passengers and their baggage, comprising a waiting room, customs examination room, and two baggage warehouses, the necessary baggage offices, and a booking office. The south side of this shed opens on to a railway platform, from which special trains will be run to Fenchurch Street and Liverpool Street stations.

The machinery employed for loading and unloading consists of 61 hydraulic traveling cranes, 55 ft. high. These cranes are distributed round the sides of the docks, but they are not fixed, and are made to run on rails 13 ft. 3 in. apart, inside of which is the ordinary railway with its trucks, the cranes being elevated upon large wrought iron frames which span the rails and allow the trains to pass underneath them, thus forming a bridge gauge for the trucks, so that when loaded to such a height that they will just pass under the cranes they are quite safe from coming in contact with any bridge or tunnel on the line. Notwithstanding the great size of these cranes, they can be moved upon their rails to any part of the dock side; and so, if rapid loading or unloading of any vessel be required, a crane can be placed over the hatchway of each hold. One can form some idea of the rapidity with which the loading or the unloading can be done when we know that each crane, which will lift 30 cwt., can have its weight attached in the ship, hoisted and swung round, have the weight deposited upon a railway truck, return to its former position over the hold, and drop the chain into the hands of the men ready to receive it for another lift in a few seconds more than half a minute. When the first crane was tested in unloading a ship at the East and West India Dock, it made 81 lifts in 47 minutes, the cargo being wool, which was lifted by four sacks at a time. The attendant of the crane and the necessary handles and valves are placed on a covered platform at the back of the crane, and swing round with it, so that whatever may be its position he remains in the same relative position with regard to the hook and slings, upon which he keeps his attention, and which he manipulates with readiness, hoisting, lowering, and swinging the crane round with the greatest ease. The means adopted for moving the trucks into position for being loaded are equally ready and effective. As soon as a truck is loaded, it is moved out of the way and another one brought into its place by means of a hydraulic hauling capstan, of which there are 26 fixed at suitable places around the docks; and so, when one train is made up, it can be moved away and another brought into its place by means of the locomotive. These cranes and capstans are made by Messrs. Tannett, Walker, and Co., of Leeds.



THE NEW EAST AND WEST INDIA DOCKS AT TILBURY, NEAR LONDON.

The pumping engines for supplying the water for these cranes, together with the water pipes and the different accumulators for regulating the pressure, are made by Messrs. Sir William Armstrong, Mitchell, and Co. They consist of three pairs of compound surface condensing engines, each pair being about 100 indicated horse power and working double acting pumps. The pressure of steam is 80 lb. on the square inch and that of the water is 700 lb. on the square inch, and this water is conveyed all along the sides of the various quays through 5 in. pipes of great strength. The supply of water is equalized by means of three accumulators, the weighted rams of which rise or fall as the pumps are forcing more or less water into the pipes than is used by the machinery. The three boilers for supplying the above engines with steam were made by Messrs Adams and Co., and have an inside diameter of 7 ft. and length over all of 27 ft.

For lifting and shipping heavy weights, a powerful floating steam crane, the Leviathan, designed and constructed by Messrs. Hunter and English, of Bow, has been provided. The vessel is 110 ft. long between perpendiculars, with 44 ft. beam and a depth of 9 ft., with two transverse water-tight bulkheads. There is also a circular bulkhead under the roller path. The vessel's propelling machinery consists of twin screw

engines capable of driving the vessel at a speed of from 4½ to 5 miles an hour. They are of the inverted cylinder type, working collectively to 150 horse power. The crane, which resembles shear legs, is designed to lift and swing 50 tons at 25 ft. or 45 tons at 30 ft., and is capable of placing masts over 100 ft. high in a ship of 50 ft. beam and 32 ft. from the top of the bulwarks to the water level. The crane mechanism is controlled by one man from one spot under the direction of the captain. The hull of the vessel is of iron, as is also the framing of the crane, but the jib, which consists of two members circular in section, is made of steel. The vessel can be run alongside a ship while lying at her berth, and can take out or put on board heavy pieces of machinery or guns while the ordinary operations of loading or discharging the ship are going on from the quay. The Leviathan has ample deck room for carrying guns, armor plates, boilers, or pieces of heavy machinery, and is so constructed that it may be used for assisting in the ordinary operations of loading and unloading cargo.

In addition to the power for dealing with the traffic, the huge dock gates have to be opened and closed by hydraulic machinery, and the graving docks are provided with pumping apparatus for pumping out the water when a ship is taken in for repairs. The lock connecting the main dock with the tidal basin is 80 ft. wide and 700 ft. long, divided into two chambers respectively 555 ft. and 145 ft. in length, and there are three pairs of wrought iron, double skinned lock gates, constructed by Messrs. Joseph Clayton and Co., of Preston. Some idea of their size may be formed when we say that each pair weighs nearly 240 tons, the width of each leaf being 49 ft. and the depth from the top of the gates to the sill 44 ft. Water can be pumped out of them at the rate of 650 tons per minute by means of four large centrifugal pumps made by Messrs. Simpson and Co., Pimlico.

Four large dry docks are provided, in which scraping, painting, and repairs can be effected. Two have a depth of 32 ft. and two 27 ft. of water on the sills at ordinary spring tides. These unusual depths will obviate all risk of the detentions so frequently experienced by ships at other dry docks within the port of London. The dry docks are inclosed and divided by caissons. The emptying of the larger pair of dry docks by pumping out 12,000,000 gallons of water can be performed in an hour. There are six caissons, constructed by Messrs. R. and H. Green, of Blackwall, of which those at the south ends of the dry docks were built in position. The other four were constructed at Blackwall. The weight of each caisson is about 240 tons. The boiler house has been constructed to accommodate six boilers; five only have been laid down. Two drainage engines and pumps are provided, and Messrs. Belliss and Co.'s fan arrangement for a forced draught has been adopted. The main dock is 1,800 ft. long and 600 ft. wide, and each of the three branch docks is 1,600 ft. in length, extending from the main dock in a northwesterly direction, the center branch dock being 300 feet wide, while each of the other two has an average width of 250 ft. The depth of the main and branch docks is 38 ft. below Trinity high-water mark. At the quays in the main and branch docks, which are 13,000 ft. in length, 31 steam vessels of the largest size can be berthed for loading or discharging, and the depth of water admits of such vessels being at all times loaded to their full draught alongside the quay without removal to the basin. On the quays of the three branch docks 22 sheds have been erected on piles.

The sheds are each 300 ft. long and 120 feet wide, while the height to the eaves is 12½ feet, and to the apex of the roof 26 feet. Each shed is inclosed by self coiling steel shutters, of which a total area of 108,000 superficial feet, or 2½ acres, has been used. The floors are of wood, the principals of iron, and the roofs of slate. There is also a dredger, constructed by Messrs. Hunter and English, of which the hull is 101 ft. long and 29 ft. beam, with a draught of 9 ft., which has actually raised 210 cubic yards in an hour of mud or ballast from a depth of 45 ft. There is also ample accommodation in the way of goods junctions and sidings and most complete telegraphic and telephonic arrangements.

It is almost needless to say that the electric light has been employed throughout the whole dock system. The work has been done under the direction of Messrs. R. E. Crompton and Co., of London and Chelmsford, and the general arrangement of the lights has been such that a total of 80 arc lamps of 3,000 candle power each have been placed in various positions on masts or other convenient posts of advantage in the outdoor part of the docks. Many of these posts are 50 ft. high, and there has been no small difficulty in fixing them securely in the marshy soil of which the docks are composed. The incandescent lamps are in nearly every case under cover, and consist in all of 1,362 lamps of 16 to 22 candle power. Five engines and boilers are employed to drive the generating machinery, and they are together capable of a *maximum* output of 500 effective horse power. They are placed in two engine houses, one near the hotel and the other at the opposite end of the docks. There are 16 dynamos of the well-known Crompton type. These machines are of the same kind as those supplied to the ships of the White Star Line, the Royal Gun Factory at Enfield, and for lighting Vienna, and are of the most improved form. They have heavy wrought iron magnets and are put together with great mechanical strength. They are among the most efficient machines that can be had, and visitors will no doubt be struck by their great simplicity of construction. Tests recently published of some large machines of this type made for electric lighting abroad show that they are the most economical machines made.

The fire-extinguishing appliances comprise two land steam fire engines, each capable of throwing a ton and a half of water per minute, one powerful tug fitted with four 1½ in. deliveries, 83 hydrants fitted to the sheds in the main and branch docks with 100 ft. head of water always charged, 2,300 ft. of brigade hose, 900 feet of hose at caissons, and two hose reels with hose ready to run to any spot, with all subsidiary appliances, gear, branches, spanners, etc.

A spacious hotel, called the Tilbury Hotel, has been erected on the river bank of the tidal basin and in immediate communication with the London, Tilbury, and South-end Railway. A row of eight houses has also been constructed for the superintendent and the principal resident officers of the dock company; there are 30 cottages for the foremen, sergeants of police, and others, and six blocks of workmen's dwellings. The railway company propose to run a frequent service of fast trains between Tilbury and Fenchurch Street, which will do the distance in about 35 minutes, so that neither the dock company nor the railway company appear to have omitted any means which would conduce to the success of this great undertaking.—*London Times.*

Our engraving is from the *London Graphic.*

SIBLEY COLLEGE LECTURES.—VII.

BY THE CORNELL UNIVERSITY NON-RESIDENT LECTURERS IN MECHANICAL ENGINEERING.

By CHAS. E. EMERY.

TRANSMISSION OF STEAM.

THE nature of the difficulties encountered in transmitting steam for a considerable distance are not generally understood. Condensation necessarily takes place, as is expected, but non-conductors may be applied to reduce this loss to so small a proportion of the carrying capacity of the pipes that it will not form a serious disadvantage in a mere commercial sense. The problem may be called difficult on account of the number of principles involved, and the mass of engineering and mechanical details required to apply the principles correctly and successfully. Condensation is but one of the many conditions to be provided for, and in some respects an embarrassing one, but it can be satisfactorily dealt with much more readily than several others.

It is proposed in this paper to discuss:

1. The properties of steam which make it well adapted for a transmission to a distance.

2. The methods adopted to maintain pressure and provide for condensation.

3. The nature of the mechanical devices necessary in a successful street system of steam pipes, with methods of insulation, of supporting and securing the pipes, of overcoming street obstructions, and of making service connections.

4. Methods of measurement; and

Lastly, a statement of precautions necessary in operating long steam pipes, of the causes and prevention of water rams, of the nature of the repairs required to a street system, with general remarks on the whole subject.

The descriptions in most cases refer to the plant and apparatus of the New York Steam Company, designed by the writer, but the same are introduced principally to show the nature of the details required in the practical application of the principles, as time will not permit a full description of this work.

The expression, "a district steam system," is now accepted as referring to a plant in which steam, generated in a central station, is distributed through underground pipes laid in the public streets so that the steam may be taken at will by consumers, "on tap," so to speak, the same as gas and water. Such a plant is in some respects similar to, and at first sight would appear to be only an enlargement of, the method of distributing steam from a central point to the buildings of a large factory or public institution. In fact, however, the conditions encountered in putting pipes in streets already full of underground obstructions, such as other pipes, vaults, sewers, etc., in such a manner that customers can be accommodated when and where desired, involve many more difficulties and require many modifications in detail, compared with a system where all the property is under one control, where space underground is rarely obstructed or valuable, and where the whole plant, with all its ramifications, may be laid out before the work is commenced.

Dry or saturated steam is well adapted for successful transmission, to a distance, for the simple reason that the temperature always corresponds to the pressure. The laws of thermodynamics show that absolute temperatures and pressures always bear a constant relation. It follows therefore that steam of a given pressure is as valuable at the distance of a mile or more from the boiler in which it is generated as it is at the boiler itself; also that a steam mixed with water, has, when the water is removed, all the properties, and is equally valuable as any other steam of the same pressure. In short, steam does not *deteriorate* the least in transmission, so long as it is steam; that is, has been freed of the water of condensation incident to its transmission. Pressure may be lost, but permit me to repeat, that the steam is as valuable as *any* steam of the same pressure.

The problem of separating steam from water is well understood. Evidently, if a mixture of steam and water be passed through a drum as large as the steam space of the boiler in which the same quantity of steam would ordinarily be generated, the water will be separated by gravity, the same as in the boiler itself. In most cases the pipes themselves act as drums. In any case, by a proper application of principles, it is possible to transmit steam to as great distances as any other fluid. The actual maximum distance must be governed by commercial considerations as to relative cost of piping and stations.

To make the steam efficient, then, it is necessary only to maintain the desired pressure at the ends of the lines, and this depends on the size of the pipes and the loss of pressure that can be permitted. Some embarrassment would result from permitting a very large loss of pressure between the boilers and the ends of the lines. The demands on the various lines are variable, and as it is necessary to keep up the pressure at the boilers sufficiently high to maintain the desired pressure at the end of any one of the branches, the pressure near the ends of the other branches will vary with the demands in such branches. This would require at certain times of the day, at least, a very high pressure at the boilers, and, for safety, the whole plant would have to be constructed to stand this pressure, so that there would be greater liability of leakage, and the first cost as well as the cost of maintenance of the boilers, pipes, and all valves and connections to which the pressure was introduced, would be increased. For these reasons the pipes of the New York Steam Company were proportioned for a loss of pressure of only 10 lb. in a distance of half a mile when the plant was at its full working capacity. All the parts were made of sufficient strength to carry regularly a steam pressure of 100 lb. It was hoped that 60 lb. would be sufficient for all the purposes required, but many more places were found than was expected in which the apparatus was deficient in size, and required 70 to 80 lb. pressure to do its work efficiently. The standard pressure in the mains has therefore been fixed at 80 lb., the engineers at the boilers being permitted a range of from 77 to 82 lb. to allow for the varying conditions incident to firing and sudden drafts on the boilers due to changes in the demand. The loss of pressure at the present time at the ends of mains ¾ of a mile distant by line of pipe from the boiler house is not over 2 lb., for the reason that the pipes are not as yet working to their full capacity. It is a curious fact, also, that occasionally in making synchronous observations it is found that the pressure at the end of the line is *greater* than at the boiler house, which is readily explained by the fact that for these low differences of pressures the velocities are so small that a change of demand on one part of the system may draw down the pressure at the boiler house before the pressure in another direction has had time to adjust itself to that at the source of supply.

The first problem in designing a steam plant is to ascertain the total quantity of steam required and the quantity necessary to supply in detail the several blocks on each of the streets through which the pipes are to be run. In New York this was approximately obtained, first, by collecting the statistics on file in the Police Department with relation to the steam boilers in place in the city, rules being given the computers by which the approximate power of a boiler could be determined from its external dimensions and type, which were the only dimensions taken by the boiler inspectors and reported to the Police Department. The aggregate cubic capacity of all the buildings within the areas which it was expected to heat was also computed approximately from the insurance maps, and this multiplied by a proper factor gave the estimated quantity of steam required to heat that space.

Complete maps on a large scale, showing the house lines, were prepared of each district, on which each boiler was located and marked with the amount of steam it would supply. Similarly, there was written on the ground plan of each building the amount of steam it would require for heating. This preliminary work, though simple in its character, involved a great deal of labor, on account of the number of streets, buildings, and boilers to be considered. When the maps were completed, the first step was to sum the several quantities marked on the buildings for each block. In locations where a boiler was marked, the steam required for heat was summed as before, but deducted from that which the boiler was capable of generating; the remainder, which was also summed in, evidently represented the steam which was required for power purposes in that particular building.

The next step was to sum together the quantities of steam required for the several blocks in the whole district, which at once gave an idea of the capacity of the boilers required and of the mains to be started out from the boiler house. The location of the boiler house having been determined, the next step was to lay down approximately the lines of the principal trunk mains, and indicate an area on the map which each was expected to supply. This enabled the desired capacity of the mains for a particular street to be determined readily by summing the quantities marked on the several blocks which were to be supplied from that street. The total quantity to be carried by the mains as they approached the boiler house was shown by the sum of the various quantities at that point, and evidently equaled the first main sum representing the total quantity of steam to be supplied from that station. In the particular case referred to, the quantity of steam shown to be necessary by this computation was much greater than it was thought expedient to provide for. It was considered that many buildings would not take the steam, and the expense of the undertaking appeared so great that at first it was thought best to not attempt to carry more than ¼ the quantity of steam thus computed. This however was afterward changed, and the plant designed to generate and convey substantially one-half of the steam at that time required on the basis stated for the district under consideration. It was well known that lower New York was being rebuilt, and that more steam would be required in the future, but it was not thought expedient to risk the success of the plant by too great an expenditure in the first instance.

The first station of the company was located on Greenwich St., between Dey and Cortlandt Sts. The building was designed to contain 16,000 horse power of boilers of the Babcock & Wilcox type, as will be explained hereafter.

It was expected that this station would supply for a number of years the demands of that part of New York city below Chambers St., but that it would be necessary eventually to have one or two more stations. The property for one was purchased on Front St., near the Battery, and it was anticipated that possibly another would be required in the vicinity of Fulton Ferry. In all, properties were purchased for ten stations in different parts of the city, but of these as yet only the one referred to at Cortlandt and Greenwich Sts., designated "Station B," has been built.

Considerable investigation was made to ascertain the proper formulæ for determining the size of pipes required to transmit the steam. The difficulty was not so much in finding formulæ, as to decide which were best applicable. As is generally the case, the simplest was finally determined upon, based directly upon the laws of falling bodies, and in form that generally used for the flow of water in pipes, simply substituting for the density of water that of steam at the pressure to be carried. Most of the experiments on the flow of gaseous fluids given in the textbooks refer to air at low pressures and with very small quantities of discharge. There were, however, some experiments on the flow of compressed air in the pipes supplying the drills in the Mont Cenis Tunnel, where the pressure and the quantity of air moved were sufficient to compare favorably with the conditions under which steam was to be transmitted. The only report of these experiments accessible was that given in D. K. Clark's "Handbook for Engineers," which stated the curious conclusion, drawn from the original report, that the quantity of air transmitted was independent of the density. This was of course impossible, as a little consideration will show. Those particular results would correspond well with the formula given in which the density was omitted, for the simple reason that the density was

nearly constant in all the experiments. By substituting numerical values determined from these experiments in the ordinary water formula with a character representing the density introduced, a general formula was obtained in which the constant very curiously and satisfactorily coincided very closely with those given by Wiesbach, in relation to the flow of air at about the same velocity as was expected in the steam pipes. It should be observed that the loss of pressure due to transmission varies also with the density of steam, so that any formula founded on a constant density is not precisely correct. As, however, the loss of pressure was to be restricted to ten pounds, the original formula were based on the average density. At a later date, however, investigations were made in which the variations in pressure were taken into consideration, the formula derived from the water formula being considered a differential formula with relation to the flow of steam. By this means a formula was obtained which, it was believed, well represented the probable facts for all steam pressures and all losses of pressure in transmission. Between the limits of pressure it was expected to use in practice it was found that practically one formula was as exact as the other, so the use of the simpler one was continued in general use. When the slope was introduced into the formula, to wit, 10 lb. per half mile, and the density, which was first fixed at that due to 70 lb., with the expectation of going from 75 lb. down to 65, the formula for the weight of steam discharged per hour reduced at once to

$$W = 87{\cdot}3\, d^{\frac{5}{2}}$$

d, being the inside diameter of pipe in inches. This form results from the fact that the areas of the pipes vary as the squares of their diameters, and the hydraulic mean depths, which are proportioned to the friction as the square roots of the diameters, so the products of the two vary as the $\frac{5}{2}$ power. For strict accuracy, some modifications should have been introduced in the formula, as the friction undoubtedly reduces as the velocity increases, and it is probable also that the friction reduces faster than the hydraulic mean depth. It was not necessary to consider these points, however, as the variations in velocity and density were so small.

In practice it was not found expedient to reduce the pipes as rapidly as the mere conditions of demand according to the maps above referred to would indicate. It was thought that possibly there might be a concentration of demand on certain lines, and it was also desirable to make provision for re-enforcing the pipes near their ends from other stations, should it become necessary. Consequently, in practice, only the lines leading to the boiler house were proportioned by the rule, and the others, as a general thing, were made larger. It was not thought best in the down town streets to lay any steam pipe less than six inches in diameter throughout the length of a long block; and although this was small by calculation for some blocks, still, as it could be fed at both ends, it was considered sufficient, and has since so proved in practice. The above formula was designed to carry the whole capacity of the pipe to its end, whereas in general practice steam is drawn off at intervals, thereby enabling the remaining quantities of steam to be carried along with less relative reduction of pressure. On the whole, therefore, considering the various conditions, it was decided to increase the value of the constant in the formula to an even 100, and the table of the carrying capacity of pipes now used is simply derived by raising the actual internal diameters of the various nominal sizes of pipe in inches to the $\frac{5}{2}$ power, and carrying the decimal point two places to the right.

Some idea of the magnitude of the work of the New York Steam Company can be obtained from the statement that there are already in position from the boiler house one 16 inch pipe, one 15 inch pipe, and one 11 inch pipe, with only part of the capacity of the building yet utilized, and that it is expected to put in in addition two 24 inch pipes, to keep up the pressure at a distance as the demand increases.

The formula shows that the carrying capacities of pipes increase much faster than their areas, and it follows that a material reduction in loss of pressure can be secured by a comparatively small increase in the diameter of the pipes and of the cost of the work.

It is found in practice that steam pipes can be so protected that the loss of condensation will be a very small proportion of their carrying capacity. Experiments were made before the plant of the New York Steam Co. was built, which showed that mineral wool, of ordinary quality, furnished very nearly the same resistance to the passage of heat as the same thickness of hair felt, and that the better qualities were equal or even superior in this respect to hair felt. As mineral wool was non-combustible, quite permanent when kept dry, and not subject to friction, and withal could be manufactured quite cheaply, it was fixed upon as the material to insulate the pipes of the New York Steam Co. In a majority of cases the pipes were suitably supported in the bottom of a trench, brick walls built up at either side, and covered with planking and roofing material, so as to leave a space of from three to four inches about the pipe on all sides in which mineral wool was placed in bulk. In some cases the wool was placed inside a wood casing of pump logs, but this was not considered a part of the regular system, and has not proved as desirable or durable as the other plan. The result of this method of covering has been that with nearly five miles of large pipe, also about two miles of smaller pipes used as services, all under steam continuously, days, nights, and Sundays, there is required but 150 horse-power, each of 30 pounds of water per hour, to supply the condensation in the mains. The mains vary from 16 inches in diameter to 6 inches, and the services are mostly three inches in diameter. This loss is so small, as has been previously stated, that it does not affect seriously the commercial problem of the transmission of steam.

The water of condensation, though limited in quantity, must be properly provided for. If in all cases steam could be transmitted at slow velocities in a large pipe graded so as to have a slight descent *away from* the source of supply, the water in the steam would separate by gravity and trickle along the bottom of the pipe, the size of the stream of water gradually increasing until means were provided to permit its escape. By taking the steam from the top of such a pipe and arranging to blow out the water at intervals from the bottom, the length of the pipe could be continued indefinitely; no inconveniences would result except the loss of pressure due to the distance, and the steam at any point would be as dry as though it came from the boiler direct. This ideal state of facts is accomplished as nearly as possible in practice. Steam must, however, at times be carried up a slope instead of down, and frequently the pipes must have undulating grades to correspond substantially with those of the surface of the ground. When the movement is up a slope, the water of condensation is to a greater or less extent entrained by the current of steam. This is particularly the case when the steam is moving at a high velocity. In practice the up grades in the direction the steam is transmitted are made as sharp and as short as possible; and beyond the summits, the down grades, in which there is a natural separation of the steam and water, are made easy and long.

This desirable arrangement cannot always be carried out; the street obstructions are frequently so arranged that the pipe can only be laid in undulating grades corresponding more or less to those of the surface. In all cases arrangements are made to trap out the water of condensation at the bottom of every dip of the pipes, so that the current of steam passing onward and upward has no more water to contend with than is condensed in the portion of the pipe to be passed over. The water is removed automatically by steam traps, and returned to the boiler house through another system of pipes called return water pipes, the details of which, as well as of the traps, will be referred to hereafter.

In laying steam pipes underground it is necessary to observe the following requirements:

1st. The pipe and connections must be of unusual strength and better put together than is customary for the pressure, for the reason that the work is out of sight and cannot be regularly inspected.

2d. The sections of pipe must be sufficiently short to enable them to be readily handled, and if necessary introduced to place through narrow spaces between other pipes already in position.

3d. It is absolutely necessary to secure tight joints, and yet desirable to do this without absolute rigidity, on account of the possible settlement of the soil.

4th. All the joints should be of a character enabling repairs and renewals to be made as required.

5th. The pipes should be supported independently upon the soil, and not be liable to strain from the filling in of the trench, and the street traffic afterward.

6th. Provisions must be made for connections at intervals; and

7th. The expansion devices should be so arranged as to be efficient, and not to interfere with either of the other requirements.

The expansion of small pipes is generally provided for by means of bends and offsets which will spring sufficiently. This method, in its simpler form, is applicable to short lengths only, but if the arrangement be well studied, pipes of any length may be laid on this system. For instance, if it be desired to run a pipe from one end of a long building to another, it may be accomplished by crossing and recrossing a sufficient number of times. No known rules for this kind of work are formulated. The workman is supposed to make the offsets of such a number and with such lateral lengths that expansion will not strain the joints. Frequently, however, insufficient attention is given to this matter, and leaks are developed at important fittings, which it seems impossible to keep in repair, and the work can only be made satisfactory by changing the system to suit the actual conditions. A modification of the offset system, with what are called swinging elbows, forms a much safer method of providing for expansion, but is less used, as more fittings are required, and some little study is necessary to adapt the work to the straight lines and flat grades necessary in a building. It is, however, a very desirable way of laying long pipes of limited size underground, and elsewhere where the grade can be changed as required.

One application of the method may be described as follows: Imagine a main line of horizontal pipe approaching the observer. The nearer end enters an elbow with outlet turned down, in which is screwed a nipple entering another elbow with outlet turned toward the right, into which is screwed a lateral pipe to form an offset of length adapted to the circumstances. The end of this pipe connects with an elbow with outlet turned down, the latter outlet with a nipple, the nipple with an elbow of which the outlet turns toward the left, in which a piece of pipe is connected, which may be of the same length as the first offset. The end of this pipe is again connected with an elbow with outlet turned down, a nipple inserted and connected to another elbow, the outlet of which connects with a pipe, which may have the same general line as the first, but should be located below it sufficiently to allow for the various drops at the nipples in the several elbows. A little study will show that this is a complete swinging joint. The pipe may expand as much as desired, and can do no injury, as it will simply screw or unscrew the nipples in the elbows slightly. Moreover, by arranging the elbows so that the elbows turn down in the direction it is desired to drain the pipe, it will be seen that the expansion does not intefere with the drainage. Evidently it is not necessary to have the direct and return arms of the offset parallel, and if desired these arms may be connected by a pipe in the direction of the original pipes, the connection always being made with two elbows and a nipple.

In this kind of work it is desirable to have the offsets of such length that there will be movement on the threads only the first time that steam is turned on, so that afterward if it be shut off temporarily the elbows will not turn, but simply spring the cross pipes a little, which strain will be relieved when steam is again turned in the pipe. Simple and efficient as this device is, it is very difficult to teach mechanics how to make it. They will think they have a swinging elbow joint if they put two elbows at one end of the lateral pipe, and only one at the other. Many in studying this plan will say, Why not use a return bend where the two lateral pipes join? but on second thought, it will be seen that this defeats the object to be attained.

Swinging elbows are also used to pass obstructions, the cross pipes being inclosed in a yoke in the steam pipe; the steam takes the upper part of the yoke, the water of condensation the lower, and drainage is not interfered with.

Stuffing boxes or slip joints are frequently used on long lengths of pipe to provide for expansion, though generally on large pipes only. This system answers very well for water pipes or where the steam pressure is low. With high pressure steam the packing has to be very compact to resist the pressure, and great care and some considerable expense are required to keep the stuffing boxes in order and prevent them from leaking. Frequently stuffing boxes are applied without due care in anchoring the pipe. Cases have occurred where pipes were prevented from sliding simply by a lateral connection coming in contact with the side of an opening in a wall or partition. In laying a number of stuffing boxes on a length of pipe without anchorages, the whole pipe may shift to the box which is loosest, and the others not move at all until the first has a very extreme movement, or, as has sometimes happened, is pushed entirely in. Sometimes in cooling such a system the sleeve of one stuffing box is pulled entirely out of the packing.

The original street system of Birdsall Holly, of Lockport, N. Y., provided for the use of stuffing boxes at intervals of 100 feet. These boxes, called "junction boxes," were each secured to one end of a length of 100 feet, and strongly anchored against the wood logs forming the covering of the pipe. The other end of each section was free to move out and in the stuffing box secured to the next section. These stuffing boxes had elongated bodies with outlets, to which connections were made for the various buildings. Simple as were these modifications of Holly's from the customary practice, they contained the basis of really the first practical system for conducting steam in straight lines underground for any desired distance with provision for connecting service pipes at intervals from points that were anchored so as to be stationary. In all cases the services were taken from the junction boxes, and offsets made either in the street or yards to reach the buildings or any part of the same desired. The value of his system is best exemplified by briefly describing a modification of it used by a company in the city of New York, started in opposition to the work of the New York Steam Company, soon after the latter was well under way.

In the case referred to, stuffing boxes were used, but they were located only at the corners of the streets in castings, which also served as crosses to connect with the main street laterals. The consequence was that expansion had to take place for the whole length of the block, and this system was carried out whether the blocks were 100 feet long or 400 feet. The pipes were carried on rollers, so that they would move freely. If mere expansion and contraction had been all that was to be provided for, the system would have worked well enough if properly constructed. In all cases, however, in street work the grade and line must be changed at intervals to avoid obstructions. These were overcome in this particular case, even for pipes eight inches in diameter, by making rigid offsets, sometimes of several feet, with common screw elbows. The friction of the stuffing boxes was so great that leaks soon developed in the elbows of these offsets, and in one or two cases the elbows actually broke, letting the steam freely into the ground, and causing what were termed explosions. Moreover, the pipes, which were supposed to be nearly straight, did not always move freely in the stuffing boxes, from the great difficulty in setting the stuffing boxes exactly in line with the pipe. It was very difficult to keep the stuffing boxes tight, and the manholes in which they were located were so hot that the men became exhausted in attempting to attend to the packing. In this system the services were taken from independent pipes anchored only at the street corners, and running for the length of the block, it being expected that there would be spring enough in the various laterals entering the house to allow for the expansion due to the length of half a block. As, however, some of the blocks were very long, it became necessary to leave considerable space in the boxing around the lateral pipes, particularly near the centers of the blocks. During the early part of the work, when steam was turned on and off frequently, the fitters would sometimes allow for expansion one way and sometimes the other. They were at first accustomed to allow for a movement of the pipe from the nearest street corner as it was heated up. When the pipes were already heated, they thoughtlessly at times left the room on the same side, for which reason, when the pipe was shut off, the contraction would cause the service to strike the boxing, which produced leaks and in some cases rupture.

In one case where connections had been made when the pipe was heated, the service was sheared off as the pipe cooled off, which was not known until steam was again turned on, when the lampblack used for insulation was blown all over the building. In one case of this kind, a break occurred on shutting the pipe off; and in repairing the break, the fitter allowed for contraction instead of expansion, without noting that the pipe he connected to was then cold, and the same service pipe was broken a second time when the street pipe was again heated. The wisdom of Holly in arranging that the fitters should only have distances of half a hundred feet to provide for by offsets, instead of half a block, could not be more forcibly illustrated. It is almost needless to say that the system in which the stuffing boxes were placed only at the street corners proved an utter failure, and its operation was discontinued after a few months' trial.

When the writer was called upon to design a steam system, it appeared to him desirable to avoid the necessity of using either slip joints, with their leaks and expense in care and attention, and it was readily seen that an elaborate system of offsets was not practicable. Experiments were therefore commenced with modifications of what are known as diaphragm joints, in which two annular disks of metal are bolted together through a separating ring at their outer edges, and the inner edges bolted to the ends of the lengths of pipe, or a single disk is bolted at the periphery to a large chamber connected with the pipe on one side, and the center of the disk to the pipe on the other. With these joints the elasticity of the disk permits limited expansion; the movement causing the disks to be dished one way or the other, as may be arranged. All these devices, when made as ordinarily proportioned, proved too stiff and had too limited a range for use in a street system.

A trial was made with cast iron pipe, cast very thin and corrugated very deeply, it being hoped that each pipe could be corrugated sufficiently so that it would safely provide for the expansion of its own length. In such case it was proposed to put in a lining of thin iron to form a smooth passage for the steam. These experiments made it doubtful if the plan would succeed, even if the pipes were corrugated the entire length. Although the cast iron was elastic within a certain limit, the great difficulties in obtaining uniform thicknesses made breaks liable to occur unexpectedly. Experiments with several plates held at the inner and outer edges were more satisfactory, but as ordinarily proportioned were too stiff, and had too little range of movement for the purpose. If the disks were originally dished in one direction with a view of forcing them first flat and then to dish them in the other by pressure, they were of course very much stiffer. Improvements were made by reducing the thickness of the plates and corrugating them annularly, but even when the plates were made of soft steel corrugated annularly as aforesaid, and six inches free space left between the inner and outer flanges, the plates still proved too stiff, so that there was danger of breaking the joints on the pipes to move the expansion joints, and it was not thought practicable to use more than half an inch movement for each of such diaphragms. Diaphragms of this kind were actually dished from one-half inch in one direction to one-half inch in the other, making a movement of one inch, but some parts of the disk developed a tendency to stiffen sooner than the rest, and the movement could not be made back and forth a number of times without disturbing the symmetry of the disk. The improvement due to reducing the thickness was, however, so great that the suggestion came to mind that if the plates could be still further reduced with safety, the available deflection would be inversely as the cube of the thickness, and sufficient movement could be obtained.

A successful expansion joint was finally made by using disks of copper less than one-sixteenth inch thick (0·04 being finally settled upon), corrugated concentrically and supported on radial backing plates which prevented the diaphragm from being distended, to rupture by the pressure.

Elaborate drawings of this device were shown upon the screen, one, called a double variator, having two diaphragms and providing for expansion from two fixed points on either side 50 feet away; the other, called a single variator, having but one diaphragm, and providing for expansion from one direction only. The services are taken from the bodies of these variators. The outlets are provided with flanges, but are plugged in the first instance, these plugs being removed as required with steam pressure in the mains by bolting a valve to the flange and removing the plug through it, by means of a special tool illustrated by a drawing. The stems of the valves are extended to the surface of the street, and may be operated through suitable openings in castings placed between the paving stones. At regular intervals of about 50 feet the pipes are connected by means of ball joints, which enable the direction to be changed slightly and take out the strain. Both the ball and plain joint flanges are made tight by the use of gaskets of thin copper corrugated annularly, which squeeze into every irregularity of the surface and become absolutely tight, even without the use of paint or putty. Pipes of six inches in diameter or less are screwed into the fittings. Larger pipes (and some have been used as large as 16 inches in diameter) are rolled into the flanges and fittings with an expanding tool. The ends of the pipes abut against shoulders, and the faces against which the expansion takes place are slightly dovetailed. The variators are provided with boxes, which cover the connecting flanges and terminate in cylinders of metal, which are built in the brickwork surrounding the variators. A number of illustrations were given of the various crosses, tees, and other special fittings required, which are necessarily made of a substantial character to resist permanently the steam pressure of 80 lb. The bodies of the crosses and tees are made globular, to better resist the strains to which they are subjected. Wherever a valve is placed in the pipe, or a line is terminated, heavy anchorage castings are abutted against the flanges in the pipes, and masonry built against the castings with wings well spread out, to engage with as much of the surrounding soil as possible, and thereby hold the pipes and fittings rigidly in position. Two lines of mains are run originally, one for steam, the other for the return water of condensation. Generally the latter main is laid lower than the other, so that the outlets of the two mains will pass each other. On Fifth Avenue, where there is rock excavation, with large water pipes lying at one side, the bottoms of both mains are put on a level, and the side outlets take out below the level of the mains, through what are called "drop crosses."

The traps used by the New York Steam Company were illustrated. They are of the bucket variety, with valves of different kinds, according to the size, operated directly by a float, or through the intervention of levers. Two forms of regulating valve were described. In one, the Curtis valve, the reduced pressure operates upon a diaphragm, which, through a secondary valve, admits steam to a piston operating the main valve. Another valve was shown in which the reduced pressure acts directly upon a piston connected with the valves and balanced by external weights or springs.

Considerable investigation has been necessary to perfect a meter which would answer all the conditions to be fulfilled in measuring steam. It is evident that if a displacement meter were used, the cylinder development would necessarily equal the piston development, calculated to the points of cut-off of the engines supplied through it. For ordinary slide valve engines, therefore, the meters would have to be practically as large as the engine or run at very much higher speeds, subject to all the difficulties incident to so doing. A small three cylinder engine has been developed for use where very small quantities of steam are required, it being expected to pass the steam at full pressure through the meter, and then reduce the pressure afterward, thus measuring only at the greatest density and the smallest volume. The conditions of use in the district now supplied require, however, another form, yet to be described.

Experiments have been made with meters of the velocimeter type, in which the velocity of the current of steam is registered by a series of indices. Mr. Birdsall Holly designed an instrument of this kind in which the current of steam struck one edge of a series of floats, like those of a paddle wheel. The jet was controlled by a clapper falling by gravity to reduce the opening to a narrow slit, through which steam passed to strike the wheel, when the quantity of steam passing through was limited. The axis of the paddle wheel was made vertical, and upon the lower end of the shaft was a resistance paddle wheel, which worked in water of condensation collected in the bottom of the case. The steam escaped freely from an opening between the two wheels. This meter has precisely the same kind of variations as any other velocimeter. When passing small quantities of fluid, the slip is very large, and the record is against the supply company. For quantities which may be called moderate to considerable, relative to the size of meter, the rate is remarkably near uniform, when everything is in order. When run to the full capacity of the pipe, the meters are not so accurate. The difficulty with this class of meters lies in keeping the friction constant and preventing wear. There must be some means of carrying the motion of the paddle wheel outside of the case. This is done by driving the axle, which passes through the stuffing box, at reduced speed, by means of gearing inside the case. Notwithstanding this, however, the stuffing box soon gets leaky. The speed of the wheel is quite high, and the bearings wear down rapidly, so that it can safely be stated that the apparatus is not a desirable one for use except at comparatively low pressures and moderate velocities.

The writer, at an early date, made up his mind that a successful meter must be based on the principle of flow through an orifice of known size, and with a known loss of head or difference of pressure. Several methods of doing this were tested. In the meter finally adopted, called a "rate meter," the steam flows through rectangular openings, governed by a valve, operated by a weighted piston balanced on the difference of pressure between the incoming and outgoing steam, the effect of which is that the steam flows through the orifice at a constant difference of pressure. The size of the orifice is regularly registered on a broad paper strip, traversed by clockwork. The result is a diagram showing at any time in the day the quantity of steam used at that time, and the total quantity may be obtained by integrating the chart. When steam is not used, the movable pencil runs on the same line with a stationary one. The paper upon which the meter record is made is printed in divisions of half an inch, numbered from one to twenty-four consecutively, to represent the hours of the day, and in starting the paper, the proper division is set at the corresponding time. The time that steam is turned on is shown by the vertical line made by the movable pencil at the beginning of the diagram, and when it is shut off, by a similar line at the end; and evidently the periods when any particular change is made in the quantity of steam used can be determined from the meter diagrams, as well as the quantity used during the intervals. It was at first considered unfortunate that a reliable meter could not be obtained, which, like a water meter, would show by differences of reading the quantity of steam used for the interval between observations directly without calculation, and without the expense of maintaining a time register at each location, and of integrating the charts afterward. This system, however, proved a blessing in disguise. The greatest difficulty in settling with consumers lies in the fact that employes waste the steam. This is particularly the case during the heating season, when steam for various excuses is left on continuously during nights and Sundays, thus increasing the time of consumption from, say, 60 hours a week to 168 hours. In many cases, too, the rate of consumption keeps uniform during the night as well as during the day, so that it is an easy matter to more than double the bills. The consumers at first naturally lay the blame to the steam of the steam company, but the meter charts have been the means of enabling the company to satisfy consumers when, and to what extent, the increased bills were due to mismanagement on their premises.

The meters and regulating valves are placed in the pipes leading from the streets to the building, and arranged with shut-off and pass-by valves, so that any part of the apparatus may be put in order without stopping the supply of steam to the building.

The lecturer then described a watchman's telltale system, in which a valve in the pipe leading to the consumer was connected electrically with a watchman's box on the exterior of the building. The watchman, being provided with a suitable recording apparatus on his person, visited the several boxes in succession, and by sending an electrical impulse from a portable battery through the watchman's box into the valve, received in turn a record which could be interpreted at the office to show whether or not the valve was open. This apparatus was used while suitable meters were being devised and perfected. Plans were also shown of the boiler house of the company.

The lecturer stated that ten plots of ground, in different parts of the city, were purchased by the New York Steam Company, in the first instance, to be used as boiler stations. There has, however, as yet been but one station built, called "Station B," which is located on Greenwich St., between Cortlandt and Dey Sts.

It was necessary to erect at "Station B" boilers of 16,000 horse-power on an irregularly shaped plot, 75 ft. in width, and on an average less than 120 ft. deep. To obtain proper floor room, the boilers were arranged in four tiers, each tier in a separate story 20 feet high, besides which the plans provide for a fifth story for coal storage and a basement for miscellaneous uses. Each floor is arranged for sixteen boilers of 250 horse-power each, which are placed in two rows, to face a central fire room. There are two chimneys, located between the boilers on the sides of the fire room, as near the center of the building as the shape of the plot permitted.

The whole capacity of the building not being needed at first, the walls were only carried up to an elevation of 88 feet 8 inches, and a temporary roof applied, so that at present there are available only three stories for boilers, and one above for coal storage. The south chimney has been practically completed. The north one was originally extended just above the temporary roof, covered and connected with the other by a sheet iron casing. In the summer of 1885 it was thought desirable to examine the interior of the south chimney and make any necessary repairs to lining, etc., for which reason it was decided to top out the north chimney with a shaft of practically half the area, which would be sufficient for summer use, while the other chimney was being examined.

There are now in place in the building, and fully connected, 35 boilers, aggregating 8,750 horse-power. Customers were first supplied with steam in April, 1882, since which time the steam pressure has been maintained continuously day and night. The coal is brought from the dock in carts and wagons, and dumped from the rear street into small cars in the basement of the rear buildings. These cars are run back to the elevators, lifted to the top of the main building, run out on tracks over coal bins and dumped, the coal descending by gravity through chutes in front of each alternate column and flowing out as needed on the several fire room floors, close alongside the fronts of the boilers. The ashes pass from the ash pans down chutes in front of intermediate columns to cars in the basement. These cars are hoisted on the elevator to the roof of the rear building, run out on tracks to the front of that building, and the ashes dumped into a chute, from which they are loaded into carts on the street below.

The boilers are of the sectional type, manufactured by the Babcock & Wilcox Company.

From lack of room, a well-established rule was necessarily disregarded, and the lower portions of the chimneys, instead of being independent, were made part of the building, the section of each being rectangular and corresponding closely to the floor space occupied by one of the boilers. Within the building the outside of the chimney walls are vertical, the offsets due to reducing the thickness of walls upward being inside the flue. Above the roof the inside of flue is parallel, and the walls are decreased on the outside, each offset being marked by a belt of granite blocks, forming a water table.

The lining extends only to the roof line, and is put in in sections, supported on the internal offsets. The lower part of each chimney, above the footings, is 32 feet long outside, and 13 feet wide. The flue at the top is 27 feet 10 inches long and 8 feet 4 inches wide. The chimneys are topped out at a height of 220 feet above high water, or 221 feet above their foundations. The tops of chimneys are, therefore, 201 feet above the grates of the lower tier of boilers, but only 141 feet above the grates of the upper tier of boilers.

The foundations of the walls of the building are at the elevation of mean high water, and the chimney and column foundations 1 foot below. An archway is provided through the base of each chimney, as a means of communication between different parts of the basement.

A fixed iron ladder is attached to each chimney, and connected at top with points and at bottom with a cable to form a lightning protector. It was designed to make the top of the south chimney with a projecting platform and iron reticulated balustrade, in which case the chimney would have been 232 feet above high water. It was hoped that by painting the balustrade prominently it would give the effect of a capital to the shaft, without the weight of actual surface projections. For various reasons, however, the top was finished with a granite coping at the elevation of 220 feet above high water, as previously stated, a simple footboard being provided about the chimney, with an iron hand-rail secured in coping stones.

Although the chimney appears slender the narrow way, it is so supported as to have ample weight to resist the overturning moment caused by a wind pressure of fifty pounds per square foot on the area of one flat side.

The shaft erected on the rectangular stump of the north chimney is octagonal in section, with one edge resting on a partition wall built in the center of the lower flue. The walls are reduced from the outside, with a stone water table at each offset. This chimney is provided with a cap constructed of wrought iron plates, supported on cast iron ribs built in the brickwork.

Main steam pipes 16 inches in diameter are arranged in front of each row of boilers on each floor, and connected to two vertical drums, which are in turn connected in the basement to the street mains. By properly adjusting the valves provided, either set of boilers can be connected with or disconnected from either drum. The two drums on each Babcock & Wilcox boiler are yoked together near the rear of the boiler, and from the yoke a wrought iron pipe is carried nearly to the main pipe in front, but at a lower elevation, where it connects with a copper pipe nearly parallel with the main pipe about 8 ft. long, which latter connects with a combined stop and check valve on the main. This bent pipe enables the main connection from the boiler to expand freely. The valve at the connection to the main is a simple metal check, which the steam is obliged to raise in order to reach the main pipe, there being provided, however, a screw from the top which can be set down to hold the check in place and make it a stop valve. When the boiler is in use, the screw is run up, and the steam passes out through the check. This arrangement has the advantage that if any rupture occurs in one boiler, the steam and water only from that one boiler will be blown out, the check valve preventing the steam in the main pipe from entering. In one case, by carelessness, water was allowed to get low in one boiler, and one of the headers was cracked. Through the crack, water issued on the fire, suddenly generating a current of steam sufficient to blow the door open and force part of the fire out upon the floor. The steam and water practically put the fire out; the other boilers supplied the demand, so that there was no fluctuation in pressure observable on the recording gauge, nobody was hurt, and if there had been no person in the building, the boiler would have taken care of itself without doing injury of any kind whatever. It will be seen that had even this slight accident occurred with all the boilers in free communication, there would probably have been so much steam in the room that the stop valve could not have been shut until the steam pressure had dropped, and the consumers of the company been greatly annoyed.

The two drums enable steam to be taken to the street by two routes, so that leaks on either can be repaired during the night without interrupting the supply to the streets. This system of duplication was so important that what is called a donkey system was also put in; that is, there is another system of steam pipes extended around behind the boilers with a small connection from each. These pipes have two connections

independent of the drums, to the main street pipes in front, and one section is connected to one of the drums.

The principal cause of accidents in the operation of large long steam pipes, underground or otherwise, arises from collections of water in the mains, when the pipes are cold or there is no steam circulating. The system previously described, of draining the mains to low points, where the water is removed automatically by steam traps, in connection with the plan of maintaining the pressure continuously, absolutely prevents any serious accumulations of water in the mains of the New York Steam Company, when the same are in use. If, however, a main be shut off for making a large connection not originally provided for, for repairs, or any other reason, intelligent care must be taken in restoring the pressure to prevent the pipes from being injured by what are termed "water rams." Any main which has been out of use for a considerable time is liable to have water in it from the leakage of steam past the connecting valves, and its condensation in the disused pipe. Again, when the main is shut off temporarily, water is likely to be introduced from the return mains through the service connections, particularly in winter, when the heating systems are connected. Check valves are put in the discharges of the traps to prevent this, but they are not always in order. To prevent the possibility of any water entering the steam main in this way, orders are given to shut off all the service connections before shutting off a main.

If steam be admitted at the top of a vessel partially filled with cold water, condensation will take place until the surface is somewhat heated, and this in connection with a cloud which forms above the surface will retard rapid condensation, so that in due time the full steam pressure can be maintained above water cold at the bottom. This phenomenon is not an infrequent occurrence in boilers in which the circulation is defective. It is therefore perfectly safe to heat up any vessel containing cold water, if the steam can be admitted from the top upon the surface of the water and so maintained. If, however, steam be blown in below the surface of the water, a bubble will be formed, which will increase in size until its surface becomes sufficiently extended to condense the steam more rapidly than it can enter, when a partial vacuum will be created, the bubble will collapse, and the water flowing in from all sides at high velocity will meet with a blow, forming what is called a water ram. In blowing into a large vessel, these explosions occur in the middle of the mass, and create simply a series of sharp noises. If, however, steam be blown into a large inclined pipe full of water, it will rise by difference of gravity to the top of the pipe, forming a bubble as previously stated; and when condensation takes place, the water below the bubble will rush up to fill the vacuum, giving a blow directly against the side of the pipe. As the water still further recedes, the bubble will get larger, and move farther and farther up the pipe, the blow each time increasing in intensity, for the reason that the steam has passed a larger mass of water, which is forced forward by the incoming steam to fill the vacuum.

The maximum effect generally takes place at a "dead end," as it is called, or where the end of the pipe is closed. Even if the water does not originally extend to the "dead end," if the pipe near it be once filled with steam which has bubbled through water on its way to that point, there may be sufficient cold metal to condense it, so that collapse will take place on the same principle as before, and the whole mass of water in the pipe be driven by the incoming current of steam against the end, sometimes with tremendous force, the effect being to cause leaks and sometimes rupture the pipe or break out the end connections. It is not necessary, either, that the end of the pipe be closed. In fact, under certain conditions, a more forcible blow is struck when the end of the pipe is open, as, for instance, when a pipe crowned upward is filled with water, one end being open and the steam introduced at the other, a bubble will in due time be formed at the top of the crown, when the water will be forced in by atmospheric pressure from one end, and by steam pressure from the other, and the meeting of the two columns frequently ruptures the pipe. Evidently, too, the same action can occur without difficulty in a level pipe, but, as previously stated, cannot in a pipe which descends away from the entering steam, so that the latter is *always above* the water.

It is evident from the above that it is always desirable in turning steam on an inclined main to introduce it from the top and let the water out at the bottom of the slope. When this can be done, any workman can be trusted to attend to it. Frequently, however, there are undulations in the pipe, and at times mains which may contain water have to be heated by letting the steam in at the lower end. In a building, the difficulty can of course be prevented by opening drip pipes at the lower end, and letting the water out before the steam is admitted. The same thing can be done with underground pipes, and provisions for this should always form part of the plans when it is known that a pipe will have to be heated up in this way. In practice, however, a street system contains so very many absolutely necessary details, that a provision of this kind will not be originally provided for, and at times it will occur that a main which it was expected to heat from the top of a slope may, from something being out of order, necessarily be heated from the other direction. Difficulties also occur in small pipes where the extra labor and expense required to provide special drains for overcoming this difficulty would not be warranted, particularly as another solution of the difficulty is available, even with pipes of considerable size.

If a blow-off opening be provided at one end of a main to be filled with steam, even if such blow-off be at the higher end, and the steam be admitted at the lower end, any water in the main can be driven out of the blow pipe, provided the steam valve be opened sufficiently wide to keep the pressure continuously maintained against the water. The explanation of this is that if the steam supply be limited, the water will run back under portions of the steam, forming bubbles which may suddenly collapse and produce water rams; but if the steam supply be practically unlimited, or at least sufficient, the steam will force the column of water back along the bottom of the pipe, as any vacuum formed will be filled by the steam driving back the water. There will be a series of small explosions, which will scarcely be heard, and do no harm, and the seething wall of water will be continually forced forward and finally out of the pipe.

Note the distinction in the two methods of operation necessary to suit the conditions. When the steam is on top of the water, it may be turned on as slowly as desired, and it is better to turn it on slowly, as thereby the heavy castings are heated slowly and are not so liable to be strained; but when steam *must* be turned into the lower end of a descending pipe, which *may* be filled with water, the valve must be opened sufficiently to establish a definite current and keep up the pressure. This will not require the valve to be wide open, but the result will be substantially as though it were so open. Practical engineers who on sea and land have had to do with turning on steam in pipes naturally recoil from turning steam quickly in any pipe, and it is very hard to explain to them the difference. I have had to take a party of men of this kind, state the reasons for action, and in one case I recollect using as an illustration that if a farmer with a pitchfork could get an officer on the run, the latter could not draw his sword, turn, and defend himself, as he would be run through before he came to close quarters. The principle applies to the water in an ascending pipe. The column of water once started, the steam, if the supply be made sufficient, follows it up so closely, and in such volume, that no condensation can take place sufficiently to stop the onward movement. The clearing of a pipe in this way requires nerve and judgment, but I have seen considerable cold water driven up hill out of a 6 inch pipe, 1,400 ft. long, with a difference of elevation at the two ends of fully 20 ft., by letting steam in at the lower end and blowing the water out on the surface of the street through a two inch blow-off pipe. The blow-off pipes are made no larger than this, even for mains 15 and 16 inches in diameter, but I do not consider that it would be safe to attempt to clear an ascending main of this size with this size of blow-off pipe. All these mains are more nearly level, have blow-offs at low points, near the valves, and can be blown off by putting steam in at or near the summit. In heating up an 11 inch pipe, only 400 or 500 ft. long, from the bottom, I have had the flange taken off the extreme end, in order to give the water free exit and prevent the possibility of a ram.

The greatest drawback, in a commercial sense, affecting all systems for supplying a fluid under pressure through underground pipes is leakage, with its direct loss of fluid, together with the expenses of inspection and repairs necessary in finding and stopping the leaks. Many gas companies in small cities and villages lose one-third of the quantity of gas generated by leakage. This proportion is generally reduced as the quantity sold is increased, but even old established companies in large cities lose 10 per cent. in this way. Large quantities of water are also wasted in the extended distribution of towns and cities.

The work of the New York Steam Company was particularly well done, with the intention of reducing this loss to a minimum; still, to the surprise of all, the loss from this cause far exceeds that due to condensation. Of necessity there are thousands of joints and many hundreds of valves with packed valve stems to the mile. If most of the valve stems and an occasional joint leaked but a trifle each, the loss in the aggregate would be comparatively large.

It is to be regretted that time has not permitted a more complete description of apparatus necessary in carrying out the principles involved in the transmission of steam, and of the particular details of the work of the New York Steam Company. I have no doubt that now you have heard so much that, in regard to many features, you feel confused rather than enlightened. Nearly every one of the branches of the subject discussed could of itself be made the subject of a special lecture, full of detail, possessing more or less interest to those who might be called upon to engage in work of this class.

I will close the engineering view of the subject by stating that I consider that all the problems are worked out and that all details are mechanically successful; and I am happy to say, also, that the returns on the very large investment of the New York Steam Company are sufficient to invite the attention of capital to new ventures of the same kind.

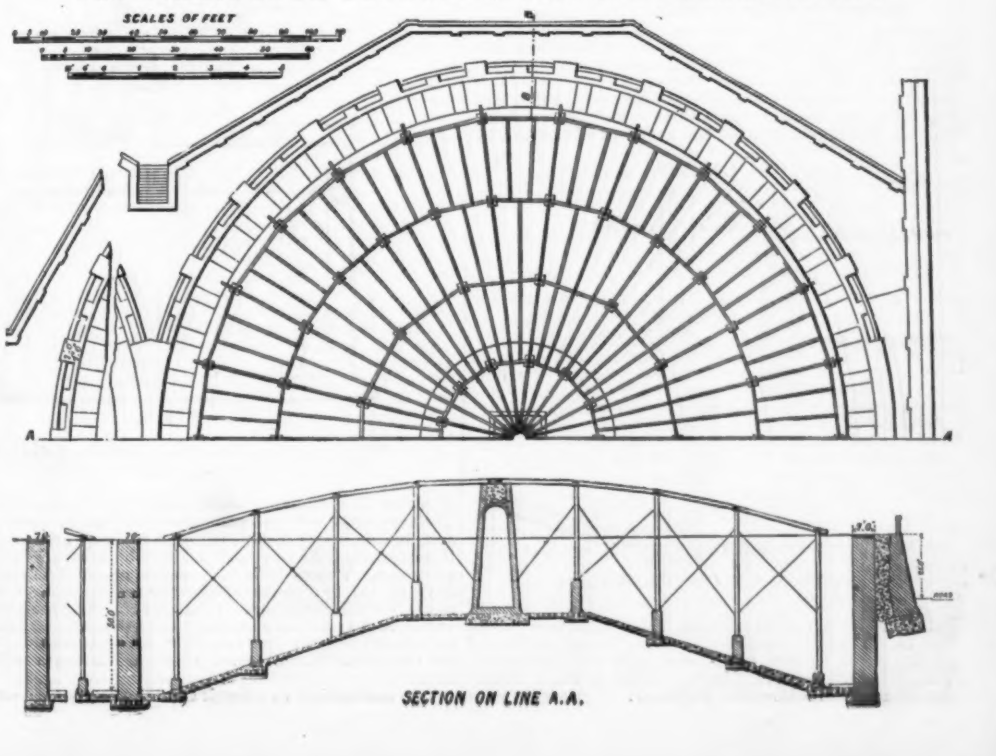
There is a field for another lecture in a popular view of the questions relating to the uses to which steam from the streets can be put, and the advantages of this method of supply. I can at this time give but a word to this branch of the subject. It will be understood that steam engines of all kinds and sizes, in any location from cellar to garret, can be operated to drive shops, furnish electric light, pump water, and the like, and that heating either with live or exhaust steam can be done on any scale, but it is also true that nearly all the *cooking* of a family can be done by steam. Nothing is lacking, in fact, but sufficient temperature to brown bread and put the finishing touch, as it may be called, upon broiled meats. Meats may be cooked perfectly with steam heat, but they cannot, in the open air, be so highly heated as to give the particular aroma which pleases the taste. Meat of all kinds can be roasted in an oven jacketed with steam more perfectly than in one heated directly by fire, as the juices of the meat are kept in, and becoming heated aid in cooking the entire mass evenly and thoroughly. Many large restaurants do all their roasting in steam ovens. Boiling of all kinds is very simply performed in jacketed kettles. An attache of the New York Steam Company has recently made an invention whereby, by planing the top of a steam table and the bottoms of the vessels to be heated, and using simple clamps, stews can be made and water boiled in vessels not jacketed with steam; the heat being transmitted from below, and the rapidity of heating or violence of the ebullition controlled simply by tightening or loosening the clamps. With steam stoves fitted with these various devices, and having in connection therewith small gas stoves for finishing the broiling of meat, and perhaps gas attachments to the ovens, to brown the bread and cake, housekeepers will be provided with a great boon. With the exceptions named, which do not form a large portion of the work, every operation can be performed by simply regulating a steam valve. By these means the objectionable features of handling coal and ashes will be entirely removed, and provision for doing most of the cooking, as well as complete facilities for heating water, and in winter for warming the building, be provided "on tap," so to speak, the same as gas and water.

Thus the sun's energy of ages past, stored in luxuriant vegetation and buried with it beneath debris due to cosmic changes, may now be redeemed from the bowels of the earth as coal, transmitted to a distance as steam, and bring sunlight to the household by lightening domestic labor. Power, heat, and even actual light may be obtained and manufactures promoted in most inaccessible and contracted places; and, gentlemen, one more subject is now available for the exercise of the talents of the engineers of the future, in their efforts to advance still further the comforts and civilization of mankind.

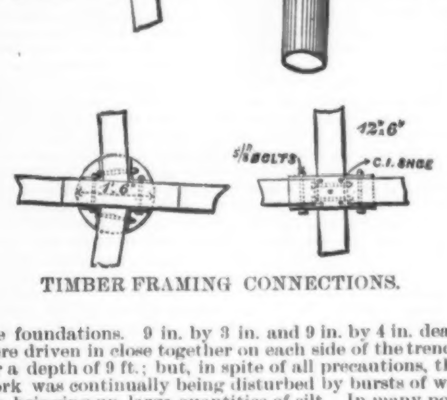
THE LARGEST GASHOLDER TANKS IN THE WORLD.

WE publish this week an illustration of two gasholder tanks recently constructed from the designs and under the superintendence of Mr. Charles Hunt, M. Inst. C. E., for the Corporation of Birmingham, at their Windsor Street gasworks. They are the largest in existence, being 240 ft. in diameter and 51 ft. deep, and are separated from each other by a wall 7 ft. in thickness. They are constructed wholly of bricks, and made watertight with cement rendering, a ½ in. coating of Portland cement and washed sand being first applied, and finished off with ¼ in. of neat cement. The substitution of this for clay puddle as usually employed is estimated to have effected a saving in the work of nearly £6,000. In consequence of the peculiar nature of the soil, which is a drift deposit, consisting of pure sand, sand and loam, with fine drift coal, the work proved to be one of exceptional difficulty, it being found impossible to effectually drain the site. For the latter purpose three pumps had to be employed, two of them reaching down to the new red sandstone, which on the very edge of the site occurs within 59 ft. 6 in. from the surface of the ground, or 85 ft. 6 in. below coping level of tanks, but is nowhere else attainable at any practicable depth. The united pumping from these pumps brought to the surface about 3,000,000 gallons of water daily, the water being kept down to a level of 87 ft. 8 in. below coping level of tanks. In addition to these, several donkey and hand pumps had

THE BIRMINGHAM GASWORKS.—240 FT. GAS HOLDER TANKS.

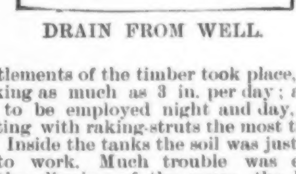


to be kept continually going in different parts of the trenches; but in spite of all efforts, the work was much of it almost under water, and the bottom for the most part a mass of slurry. It became necessary to form an artificial foundation for the walls, which was done by excavating a further depth of 2 ft. 6 in. in short lengths, covering the bottom with two thicknesses of 3 in. elm planking, and filling in on the top of these with 2 ft. deep of Portland cement concrete. In addition to this, sheet piling had to be resorted to for keeping back the slurry and preventing it from rising up underneath



TIMBER FRAMING CONNECTIONS.

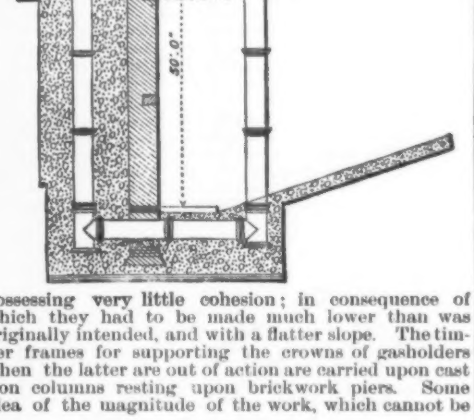
the foundations. 9 in. by 3 in. and 9 in. by 4 in. deals were driven in close together on each side of the trench for a depth of 9 ft.; but, in spite of all precautions, the work was continually being disturbed by bursts of water, bringing up large quantities of silt. In many portions of the trench the slurry had to be baled into the skips, and rose almost as fast as it was removed. Con-



DRAIN FROM WELL.

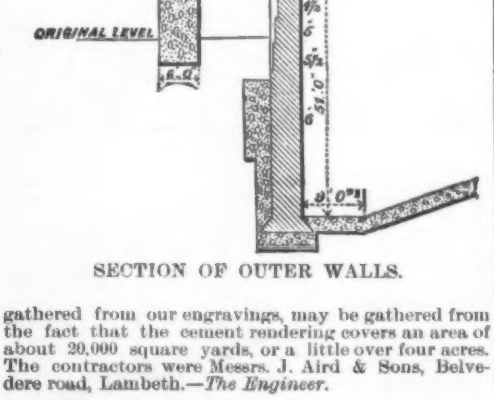
tinual settlements of the timber took place, the frames often sinking as much as 3 in. per day; and timbermen had to be employed night and day, jacking up and strutting with raking-struts the most troublesome portions. Inside the tanks the soil was just as bad and difficult to work. Much trouble was experienced through the slipping of the cones, the loamy clay

SECTION THROUGH WELL.



possessing very little cohesion; in consequence of which they had to be made much lower than was originally intended, and with a flatter slope. The timber frames for supporting the crowns of gasholders when the latter are out of action are carried upon cast iron columns resting upon brickwork piers. Some idea of the magnitude of the work, which cannot be

SECTION ON LINE B B.



SECTION OF OUTER WALLS.

gathered from our engravings, may be gathered from the fact that the cement rendering covers an area of about 20,000 square yards, or a little over four acres. The contractors were Messrs. J. Aird & Sons, Belvedere road, Lambeth.—*The Engineer.*

THE FRIEDRICH STEAM ENGINE.

THE accompanying figures represent a type of motor devised by Mr. Friedrich for domestic purposes and for the use of the smaller industries. As may be seen from the figures, the motor and boiler are united. The boiler consists of a steel plate, *b* (Fig. 2), to which is affixed a series of vertical tubes, *a a*, the lower part of which are outside of the direct action of the firebox. Upon this plate rests a forged iron frame, *d*, which supports an upper plate, *c*. The whole is held by bolts.

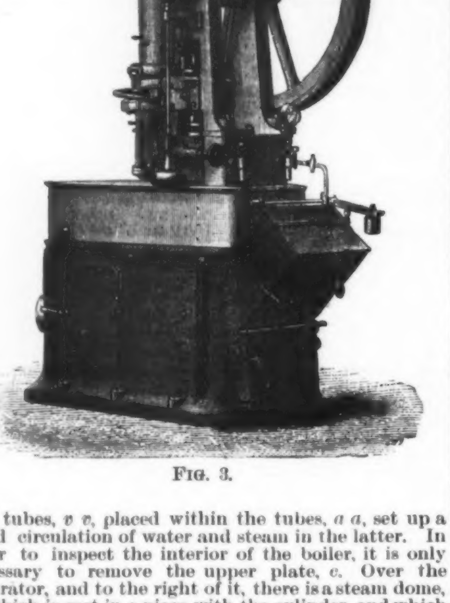


FIG. 3.

The tubes, *v v*, placed within the tubes, *a a*, set up a rapid circulation of water and steam in the latter. In order to inspect the interior of the boiler, it is only necessary to remove the upper plate, *c*. Over the generator, and to the right of it, there is a steam dome, B, which is cast in a piece with the cylinder, and which is surmounted by a frame, E, that carries the different parts of the engine. At one side may be seen the feed pump, F, which is actuated by an eccentric that also moves the value rod, *l*. The running of the engine is regulated by a good governor, which, when a power of four houses is reached, acts upon an expansion gear, while a condenser, R, of peculiar form receives the waste steam, which is afterward forced back to the boiler in an aqueous state by the feed pump. It is, therefore, always the same water that is used, and the bulk of the latter remains sensibly constant in the boiler, and thus no incrustation occurs. In order to make up for the small losses of steam that are inevitable during the running of the engine, it suffices to allow a few pints of water per day to flow drop by drop from the small condenser cock.

The necessary arrangements have been provided for removing from the condensed steam all fatty matters derived from the lubrification of the cylinder. These, by virtue of their less density, collect in the receptacle, *o*, from whence they are drawn by means of a purge cock.

The condensation of the steam requires a circulation

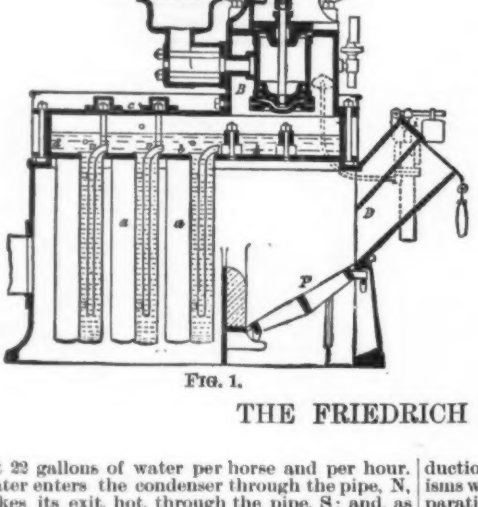


FIG. 1.

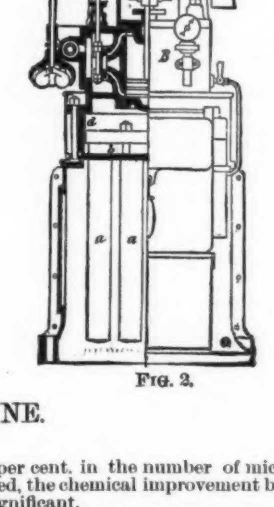


FIG. 2.

THE FRIEDRICH ENGINE.

of about 22 gallons of water per horse and per hour. This water enters the condenser through the pipe, N, and makes its exit, hot, through the pipe, S; and, as it has retained its purity, it is fit to be used for various purposes. Where it is a question of small motors, it may be led to a reservoir in order to cool, and be used anew for condensation. Finally, in cases where there is a lack of water for condensation, the motor is capable of operating with free eduction, when its running will be regular, although some of its advantages will be lost.

It is interesting to remark that the hopper, D, of the firebox contains a quantity of coal that corresponds to two hours of work. In this way the fuel distills before falling upon the grate, and afterward burns without the production of smoke. Moreover, owing to the quincuncial arrangement of the vaporizing tubes, the utilization of the heat produced in the furnace is perfect, as is proved by the low temperature that the gases possess on escaping into the chimney.

For regulating the combustion according to the discharge of steam, there is fixed to the side of the hopper, P, an apparatus that acts automatically upon the damper, *i*, in such a way as to open or close it according as the pressure rises or falls. This regulator operates with accuracy, and prevents the production of steam at too high a tension.

What precedes shows the uselessness of having a stoker permanently near the engine.

The boiler and engine are strongly built, and all the parts are grouped with judgment, and are readily accessible, so that cleaning may be effected with ease. This latter operation, moreover, is necessary only after the engine has been running for some time. Repairs are easily made, although not often necessary. The front and back plates of the boiler can be unbolted in a few moments, so as to expose either the interior of the firebox or the space that contains the tubes. If need be, the engine can be set up by itself, either on a cast iron base or on a masonry or stone foundation. It takes up but little space, and its condenser may be annexed to it. So, too, the boiler may be constructed and set up separately. It is inexplosive, its power of vaporization is relatively great, and it is quickly put under pressure. Any sort of fuel may be used. The consumption of the latter is moderate, it being not over 5¾ pounds of coal per horse and per hour.—*Revue Industrielle.*

WATER PURIFICATION.

AT a recent meeting of the Institution of Civil Engineers, the paper read was on "Water Purification: Its Biological and Chemical Basis," by Percy F. Frankland, Ph.D., B.Sc., F.C.S. The earliest attempts to purify water dealt simply with the removal of visible suspended particles; but later, chemists turned their attention to the matters present in solution in water. Since the advance of the germ theory of disease, and the known fact that living organisms were the cause of some, and probably of all, zymotic diseases, the demand for a test which should recognize the absence or presence of micro-organisms in water had become imperative. It was, however, only during the last few years that any such test had been set forth, and this was owing to Dr. Koch, of Berlin. By this means the only great step which had been made since the last Rivers Pollution Commission had been achieved. It had been supposed that most filtering materials offered little or no barrier to micro-organisms; but it was now known that many substances had this power to a greater or less degree. It had also been found that, in order to continue their efficiency, frequent renewal of the filtering material was necessary.

Vegetable carbon employed in the form of charcoal or coke was found to occupy a high place as a biological filter, although previously, owing to its chemical inactivity, it had been disregarded. Being an inexpensive material, and easily renewed, it was destined to be of great service in the purification of water. Experiments were also made by the agitation of water with solid particles. It was found that very porous substances, like coke, animal and vegetable charcoal, were highly efficient in removing organized matter from water when the latter came in contact with them in this manner. Also, it was found that the well-known precipitation process, introduced by Dr. Clark, for softening water with lime, had a most marked effect in removing micro-organisms from water. In the case of water softened by this process, it was found that a reduction of 98 per cent. in the number of micro-organisms was effected, the chemical improvement being comparatively insignificant.

Water which had been subjected to an exhaustive process of natural filtration had been found to be almost free from micro-organisms. Thus, the deep-well water obtained from the chalk near London contained as few as eight organisms per cubic centimeter, whereas samples of river water from the Thames, Lea, and Wey had been known to contain as many thousands. The water supplied to London had been regularly tested during the last fifteen months, and most important and valuable

information had been obtained as to the efficiency of the processes to which the water companies subjected the water supplied by them in removing micro-organisms, the average reduction during the last four months of the past year having been 97·9 per cent. for the Thames and 98·7 per cent. for the Lea. The biological testing of waters was of especial value to waterworks engineers, for they now had a means of ascertaining with exactitude the working condition of filter beds, instead of following the empirical methods generally in use.

[Continued from SUPPLEMENT, No. 542, page 8659.]

ARTESIAN WELLS.

REQUISITE AND QUALIFYING CONDITIONS OF ARTESIAN WELLS.*

By THOMAS C. CHAMBERLIN.

RAIN-FALL.

FOR the ultimate source of these fountains we are led up manifestly to the clouds, and the chief question relates to the adequacy of the supply they pour out upon the collecting area. There lurks an ambiguity, however, under the term adequacy. To what adequate? To furnish all that we can use and waste, or all that the strata may drink? The amount that may be desired is diverse in the highest degree, embracing the moderate needs of the farmer for his kitchen and cattle, the larger service of the manufacturer for his different uses, the great consumption of cities for their baths, sewers, lawns, and streets, and the almost limitless demands of irrigation. If there were no limits to the available supply, it would be difficult to set bounds to the drafts that would be made upon it. On the other hand, the amount which the strata can drink in, carry underground, and deliver through the well has much more definite limits; and this is clearly the better standard by which to judge the adequacy of the rain-fall, for when it has furnished to the strata all that they can take and deliver, it can do no more. It is adequate to the existing conditions, if not to our possible desires. Any failure to yield more is chargeable to the earth and not to the sky.

Still, in the absence of a full knowledge of the subterranean conditions, the possible competency of the rain-fall may be considered.

Contrasted Ratios of Supply and Demand.—Very generous or very meager possibilities will result from computation, according to the region put under estimate and the want to be supplied. In the more humid districts the wants of the land are satisfied and the artificial demands are limited chiefly to domestic and sanitary uses. The supply is great and the demand small. In the more arid regions the land is thirsty also, and there is an enormous demand for irrigation. The supply is small and the demand great. So, unfortunately, the greatest demand and the least supply are mated.

The ratio of rain-fall to domestic needs is usually high. There falls upon every 50 feet square in average habitable regions more than the highest *per capita* allotment of cities, even under a Parisian régime. But the ratio of rain-fall to agricultural demands, though sometimes high, is often low. The precipitation upon the 50 feet square falls far short of furnishing food-support for an individual. The shadow of an ox covers half space enough to collect the water he drinks, but it would be a very partial supply for the sward he grazes.

While, therefore, in humid regions the rain-fall, considered apart from loss, is usually ample for the demands which there commonly arise, a little inspection shows that in arid regions it is quite inadequate for the demands which *there* arise.

IRRIGATION BY ARTESIAN WELLS.

Artesian wells do not manufacture water. They do not even bring to the surface more than goes down from the surface. The total water supply of any given region is not, therefore, increased by them. They merely pour out at one point what has fallen and sunk elsewhere. If the total fall is inadequate to the agricultural wants of the total region, artesian wells cannot make it adequate. They may concentrate a sufficient supply upon a part, but cannot supply the whole.

If the rain-fall of a district is but half what is necessary for agriculture, only half of it can be cultivated; but even to do this the entire quantity that falls upon one-half must be transferred to the other. This is quite impracticable, for if the agencies of both surface and underground streams were perfectly combined, there would still be the large loss from evaporation. The inadequacy of artesian wells under these conditions is apparent.

Artesian wells do not, and in the nature of the case cannot, collect their supplies from the whole face of the land, but only from the surface of the outcropping edge of the porous stratum. This usually occupies much less space than the country under which the stratum lies, and which would draw upon it for an irrigating supply. This holds true also of groups of porous beds that may underspread a given region. Now, when, bearing this disproportion of areas in mind, it is further considered that evaporation and surface drainage dispose of a large share of the rain-fall, and the wells must fail to deliver all that enters the strata, it is manifest that only very temperate hopes can be built on this as a resource in irrigation under conditions of high aridity.† We must not, however, overlook some compensating conditions.

1. *Equalization of Supply.*—The porous stratum acts as an equalizing reservoir. The water runs in spasmodically, according to the varying rain-fall. It is delivered with much uniformity. The extra precipitation of wet months is thus distributed over the dry. In situations in which only a small supplementary amount in the dry months is needed, this equalization may be made a serviceable feature.

2. *Supplemental Reservoirs.*—As the water is needed for irrigation only during the productive months, while the flow is perennial, local reservoirs may be filled in the non-growing seasons, and used when needed.

* From the Fifth Annual Report of the U. S. Geological Survey, J. W. Powell, Director.

† This has been well argued by Dr. C. A. White in "Artesian Wells on the Great Plains," North American Review, August, 1882; also Report of a Geological Commission appointed to examine a portion of the Great Plains east of the Rocky Mountains, and report upon the localities deemed most favorable for making experimental borings, Department of Agriculture, Washington, 1882. C. A. White, Samuel Aughey, and Horace Beach, commissioners.

This does not essentially differ from the reservoir system as applied to surface streams, save that it has advantages in localization, security from floods, and ease of control. Both are limited by their expensiveness.

Quite a small rain-fall would suffice for crops if it were utilized to the best advantage. Deluging showers, seasonal floods, and winter rains are wasteful dispensers. If the rain-fall of the dry Western regions could be distributed so as to be most serviceable, the unproductive tracts would be reduced to very narrow limits. In so far as artesian wells can be made to subserve this better distribution, they are a valuable aid.

Advantageous Transfer.—The porous beds beneath a dry tract may receive supplies from a more favored district. Often the upturned edges of the beds form the foot-hills of mountainous ranges, which are condensers, and receive a notably increased precipitation. Artesian streams, springing from beds thus favorably situated, become a means of transfer from more humid to more arid tracts, and, to that extent, tend to equalize the distribution in space, as they have before been shown to do in time. The draft upon the source has little prejudicial effect there, while it is a boon to the more arid district.

4. *Reutilization of the Water.*—When water has once passed through the soil into the strata below, its agricultural usefulness is largely exhausted, until some agency again brings it to the surface. It is not entirely useless, for, by saturating the deep beds, it prevents succeeding rains from penetrating so far as they otherwise would, and, by thus arresting them nearer the surface, retains them in a more favorable position for utilization by capillarity and deep-root penetration. But such utility is limited, and at best small, compared to the advantage that might be gained by returning the water to the surface and redistributing it to the vegetation. It is clear that the greatest agricultural utility will be gained by continually bringing back to the soil the water that tries to run away, either on the surface or underground. In a perfect utilization there would be no streams, either above or below ground. The rain-fall would be absorbed by the soil, and thence by the plants, and by them returned to the atmosphere, the only loss being the inevitable evaporation from the moist soil. Of course, other valuable uses of water would thus be sacrificed to gain the highest agricultural utility. Now, artesian wells bring back to the surface water that had reached an unavailable depth, and permit it to be used a second time, to the advantage of both vegetation and the atmosphere, into which it is evaporated. There is in this an actual gain in utility, not a mere transference. There is, indeed, in some small measure, a greater total gain in using artesian than river water for irrigation, since the latter, in any case, aids by evaporation and lateral percolation, while the artesian stream is buried beyond use beneath impervious strata. These considerations urge as large a development of artesian wells in arid regions as practicable. While it is useless to think of them as a resource competent to restore productiveness to the total dry area, or even any great percentage of it, they form one of several means for its amelioration, which, when together brought into action, will react upon the climate in some measure, and, through it, feed their own sources. If the great volumes of water which, the Colorado, Columbia, Missouri,* and other streams, above and below ground, bear away from the arid provinces could be led out upon the thirsty plains, absorbed, and given again to the atmosphere, very notable direct and indirect benefits would follow. To hope to accomplish the whole of this is doubtless utopian; certainly, to compass any great measure of it by artesian wells is chimerical, but it is none the less important to do all that is possible now, hoping, through the aid of its reactive results, to reach larger benefits in the growth of the future.†

ADEQUACY OF RAIN-FALL MEASURED BY CAPACITY OF STRATA.

Let us now return from the general limitations that relate to the competency of rain-fall, in its totality, to the more practical question of the relations of precipitation to the water-carrying capacity of strata. Any surplus beyond what can be drawn through the strata, however valuable otherwise, is no aid to the artesian yield. Let us seek a condition of equilibrium for our starting point. Let it be assumed that, under the collecting area, the water in the porous stratum stands at any given depth. If this is not high enough to give a flow at some favorable point in the distance, the case does not fall within our province, the rain-fall being wholly inadequate. Let the rain-fall be a little less meager, so that some head is gained. A well opened at the proper point will draw upon this supply in proportion to the facilities for subterranean passage. If these are free and open, a sufficient number of wells may entirely draw off the head and stop the flow from exhaustion. The remaining water will stand in equilibrium.

Taking this as a base level, let us consider the effect of various stages of increase in the rain-fall. For a time, every increase of the rain-fall will directly augment the flow. The ratio of increase of precipitation and flow will remain nearly equal until the facilities for traversing the strata begin to be taxed. If precipitation be increased beyond this, the first effect will be to raise the head. This will increase the force by which the water is pressed through the stratum, and augment the flow, but in a diminished ratio. Every further increase of rain-fall will add to the head, and likewise to the flow, until the water in the porous bed rises practically to the surface. Beyond that point, of

* Professor Powell has suggested that the utilization of the Missouri and other detritus-laden streams in irrigation would furnish at least a partial solution of the serious engineering problems they present.

† The State Engineer of California reports, among other interesting facts, that 1,800 acres are irrigated by artesian wells in the counties of Los Angeles and San Bernardino. Nearly the maximum possibilities seem, however, to have been reached there; and although similar wells have been obtained in the great valley of California, we are not encouraged to think they will yield very great aid. (Rep. State Eng., Part IV., 1880. W. H. Hall, State Eng.; J. D. Schuyler, Asst. Eng.)

The Government commissioners above named give some of the results of attempts to secure artesian water on the great plains in the report previously cited.

Miss C. A. Salisbury, a teacher of Denver, informs me that a considerable number of successful wells have recently been sunk in that city, and that others are in progress. As yet no appreciable interference has been noticed.

Information from Hon. Horace Beach and others, as this is going to press, indicates that the number is approaching one hundred.

course, an increase of the rain-fall has little effect, for the excess flows away on the surface or is lost by evaporation.

Now, when the strata of the collecting tract are shown to be full by such overflow, we are furnished with a direct indication, not only of a competency of rain-fall, but of, at least, some surplus. Herein is afforded a practical means of determining conditions, previous to actual trial by boring. The average height of the common water-level of the collecting area, as shown by wells, measures essentially the elevation of the fountain-head. If great fluctuations are produced in these by varying rain-fall, a corresponding effect will be felt by the proposed wells; but, if they are essentially constant, the element of precipitation may be assumed to be already high enough to lend its best aid, for stability is not likely to arise from any other cause than a surplus, regulated by an overflow. If this is not apparent, let a surface lake be taken as the representative of the undeground one. Lakes which have no outflow are raised by rain-fall and lowered by evaporation and percolation, and of course fluctuate with dry and wet seasons.

Those which are well fed and have an outlet are nearly constant, for the obvious reason that the inflow will supply loss from evaporation and percolation in dry seasons, the overflow being slackened, while the overflow will draw off the surplus of wet seasons, being increased to meet the demand. The fluctuations are, therefore, confined to the few feet necessary to adjust the discharge to the surplus. So, when the subterranean water-body has no outflow, except percolation and evaporation, through capillarity, it must grow with the increase of rain-fall and shrink with its decrease; but when fed to overflowing, its surface is kept constant by the discharge of the surplus. Constancy in the level of a lake, amid changes of rain-fall, points clearly to an adequate supply and a regulating outflow. So constancy in the surface of the subterranean accumulation is a sign of a sufficient supply and an overflow of the surplus. In this case, to be constant is to be full.

There is also a rude index of the surplus in the water, which, having been once absorbed into the upper edge of the porous bed, issues again in springs. If the porous bed were not already full, we must conclude that the water would descend into it and remain. It only comes forth because the stratum, being full, cannot admit it. Water may be shed from the surface while the earth below is still not saturated; but, having once entered a continuous porous bed, it can only be assumed to reissue because it cannot penetrate deeper.

These indications show the *existing conditions* of the supply, whether the stratum has been tapped or not, and serve as a guide for the next following enterprises. If, with additional wells, springs in the collecting tract dry up, and the water level sinks, without other assignable cause, there is reason to apprehend that the draft is being felt at the fountain-head in the consumption of the surplus, if not in the reduction of the reservoir.

Accepted with qualifications, the general judgment may be expressed that in regions which have sufficient precipitation for successful agriculture, the atmosphere pours upon the upper edge of the porous strata all that distant wells are able to draw through them. There will be some exceptions where enormous drafts are attempted under conditions exceptionally favorable for the exhaustion of the supply. But these are cases in which special study of all the conditions should be made before the enterprise is undertaken. There may be exceptions, also, when the carrying capacity of the porous bed is very great, while the collecting area is limited. But the general statement is fairly reliable in its application to the usual undertakings of citizens and corporations.

In that class of wells that are derived from the drift, or other local unconsolidated surface beds, more variation is experienced, and a closer relationship to the full measure of precipitation is observed. For in these (1) the beds of passage are usually open layers of sand and gravel, which permit a free flow of the water, (2) the reservoir is near at hand, so that the resistance between it and the well is small, and (3) the collecting area is usually limited. Under these conditions a large number of capacious bores may easily draw off all that the rain-fall can supply to the limited collecting area. Hence the amount of flow will fluctuate somewhat closely with the amount of rain-fall.

The cases in which an increase of rain-fall beyond a certain moderate amount will be most markedly felt are those in which the conveying capacity of the water-bearing bed is great, and the restraining power of the overlying beds imperfect. But if the water-bearing bed is close-textured and the cover-beds water-tight, a moderate rain-fall will furnish to the collecting tract more than the stratum can deliver to any practicable number of distant wells, and will maintain the head near its maximum elevation.

From the foregoing considerations it appears that in a large class of wells of inferior stratigraphical conditions the amount of the rain-fall, beyond a certain moderate measure, is nearly, though not entirely, immaterial; whereas, in the class of more generous native capabilities, it is an element of supreme consequence.

ESCAPE OF WATER AT LOWER LEVELS THAN THE WELL.

It is manifest that if the confining beds are pierced either naturally or artificially at a point lower than the surface of the well, the water may find relief from pressure by escaping there, and fail to flow from the well. This is not often a source of failure from natural causes, where the overlying strata are thick, since the tendency in the deeper beds is rather toward the closing of openings and the healing of fissures than to the opening of a free passageway. However, in those regions in which profound fracture and displacement are common, failure from leakage through fissures is a source of apprehension.

The artificial defects consist mainly of wells previously sunk. It is a well-known fact that, where several are located near each other, those which are lower than the proposed well may already have consumed the full delivering capacity of the water-bed. The reverse may also happen. The new well, if lower than the previous ones, may draw off their flow. The remedy in these cases is simple. Either the flow of the lower wells may be reduced until the upper ones discharge, or else all

may be brought to the same level by tubing. There is, perhaps, no better test of the delivering capacity of the water-bed than the degree of interference of neighboring fountains. In proportion as the supply is generous and freely delivered at the well, interference will be decreased. Notable interference of wells is a clear indication that some approach has already been made toward the limit of productiveness for that vicinity.

A hidden source of failure may be concealed in old deep wells, which either never were put under proper control, or which have fallen into neglect. The water may rise through these into loose superficial deposits or higher permeable strata and pass off horizontally, and thus afford relief of pressure without discovering itself at the surface. The remedy is either to block up these old wells deep within the confining bed, or else put them under the same control as the new one.

CONDITIONS RELATING TO THE WELL ITSELF.

1. *The Rate of Delivery.*—It has already been made sufficiently evident that, however great the supply at the fountain-head, if the water must pass for a long distance through a thin sheet of close-grained rock, the rate of delivery at the well will be slow. If, on the other hand, the texture of the rock is open and the bed thick, the supply will be, other conditions favoring, very abundant.

A second condition of delivery relates to the well itself. It is clear that, if the bore merely touches the upper surface of the water-bearing bed, only a small space is afforded for the entrance of the stream. If, on the other hand, the well penetrates the formation deeply, the water can run in all along the sides, and, though the inflow at any one point may be moderate, the total amount from the large surface presented by the sides of the bore may be great.

Methods of Increasing the Flow.—a. Torpedoes.—Even where the entire thickness of the porous stratum has been penetrated, and all the advantages to be secured from increase of surface, in so doing, have been exhausted, the supply may still remain deficient. In some cases, the yield is notably less than good reason gave encouragement to expect. The porosity of any bed is apt to be varying, and a well may be unfortunate in passing through a close-textured portion; or, if the water-bearing character is dependent on fissures and channels, these may have been missed, though they may lie close at one side. In such instances, an effective means of promoting a flow is found in the firing of explosives within the bore.* The manifest effect of an explosion is to fissure the beds extensively about the bore, and greatly facilitate the inflow. In the oil regions this device has been extensively used, and found both practicable and effective.

b. Enlarging the Bore.—An obvious means of increasing delivery is an enlargement of the bore of the well. So far as this is intended to increase the surface within the porous bed, it is manifestly both inferior and more costly than torpedoing where the well is deep, but it has an obvious advantage in the larger conduit it affords for outflow. It is the practice of many drillers to first sink a well of the usual small dimensions, and then ream it out to the larger diameter

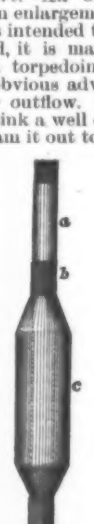


FIG. 25.—Seed-bag: *a*, delivery tube, leading to the surface of the well, and terminating below the seed-bag; *c*, a leather bag filled with dry flax-seed; *b*, marline wrappings to secure the end of the seed-bag.

desired. Besides the advantages in drilling, this renders the cost of testing the chances at that point less. From the character of the flow obtained by the first operation, it is possible to anticipate what will be the probable result of the enlargement. If the water issues with great force, it is manifest that the larger bore will greatly increase the delivery, because, in addition to the increased size, the friction is relatively less. If the flow be gentle, and the head known to be high, it is clear that the conveying stratum must interpose obstacles, and the indications are unfavorable to a very great increase from the enlarged well. If the fountain-head is low, a full gentle flow is the natural sign of a generous stream, which might give an almost equally flush discharge from the enlarged bore.

* Mr. John F. Carl, of the Pennsylvania Geological Survey, has given a very clear and detailed description of the construction and use of the torpedo chiefly employed in the oil regions. Second Geol. Surv. Penn., Oil Regions, iii., 1880, p. 267.

c. One Large or Several Small Bores?—In demands for large volumes of water, as in the supply of villages and cities, the alternative of one large or several smaller wells is presented. On this question, the following suggestions may be offered. If the capacity of the water-bearing bed is known, or, from evidence, is confidently believed to be amply sufficient to pour into the base of the well all the water demanded from its mouth, so that the question becomes merely one of providing a suitably capacious delivery tube, it is manifest that, within the limits of economical drilling, the advantage lies with the single large well. But, in all cases where very large supplies are needed, and especially in all cases where the possibilities of the water-bed are liable to be taxed to their utmost, advantage may be derived by sinking several wells separated by intervals; for a much larger area of the productive stratum will thus be drawn upon. The vital issue, in this case, is not so much the providing of means for the water to rise to the surface, as the aiding of the water-carrying stratum in delivering it to the base of the wells. It is clear that the porous rock about the base of a single well, even though it be large, cannot furnish as great inflow as the rock about several wells, though they be individually, and even collectively, smaller. Besides, if torpedoes are used, the intake of each smaller well may be made approximately as great as that of the large one.

d. Distribution of Wells.—In the employment of several wells, their distribution is a matter of some consequence. The normal direction of flow when it is once set up by virtue of the opening of an avenue of discharge is along a line drawn from the outcropping edge of the bed down its slope to the wells. Now, it is clear that if several wells are arranged along this line, the first one will be better placed than those which stand in its lee. These will be, indeed, measurably supplied by lateral flowage under the law of equal pressures, but less directly and freely. If the wells are disposed in a cluster, those on the exterior will partially cut off the supply of the interior wells. A more fortunate disposition than either of these would be an arrangement in a line at right angles to the direction of flow.

A still more advantageous arrangement, subject to local modification, would be to dispose the wells in a curved line, convex toward the collecting tract; for when the draught of the wells has made itself felt upon the sheet of water flowing most directly from the collecting belt to them, the higher pressure which the flanking portion still suffers will cause a lateral inflow, and the curved disposal of the wells will be more favorable for receiving the ingathering currents than a rectilinear arrangement, being more nearly normal to the resultant pressure and flowage.

In respect to the degree of separation of the wells, it is obvious that so far as the mere question of the

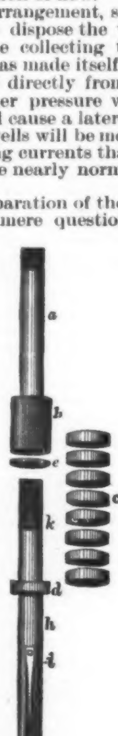


Fig. 26.

Fig. 27.

FIG. 26.—Rubber packing, shown apart; *a*, section of delivery tube, extending to the surface; *b*, a large thimble into which *k* screws; *e* an iron washer; *c*, a set of rubber disks, fitting on *k*, between *b* and *d*; *k*, a section of pipe on which is turned a long screw fitting in the thimble *b*; *d*, a disk forming the head of the screw *k*; *h*, a section of pipe extending about two feet below the packing; *i*, a spring to press against the walls and hold the pipe *h*, while the section *a* and thimble *b* are screwed upon *k*.

FIG. 27.—Rubber packing, shown screwed together as it is in the well.

greatest reception is concerned, the farther they are apart the better, for they will affect each other less; but, of course, practical considerations put a limit to their dispersion.

LOSS OF FLOW IN THE WELL.

Having previously considered the favorable and unfavorable conditions that relate to the source and underground course of the flow, we were led, in the last paragraphs, to touch upon some considerations relating to the well itself. Let us now come more squarely upon the topic, and search for causes of retardation in the well.

1. *Friction.*—We have already incidentally referred to the fact that an increase in the diameter of the well diminishes the relative amount of friction, and that so far as this element alone is concerned, the advantage lies with the larger wells. The introduction of a small delivery tube at the top of the well obviously increases the friction and diminishes the flow. There is an illusive impression abroad that a reduction of the size of the delivery tube will increase the height to which the water will flow. This is altogether fallacious. It perhaps arises from the fact that a reduction in the mouth of a discharge pipe may be made to increase the force of the jet thrown out; but this jet never rises so high as the water would in an open tube carried upward, and the water will rise to the same height in a large tube as in a small one.

2. *Lateral Leakage.*—In being forced up, the water will flow off sideways at its first opportunity. If, therefore, at any point in the upper portion of the well, it finds a crevice, or channel, or a porous bed, which is not occupied by water under as great pressure as itself, it will escape laterally, instead of forcing the column to the surface. It is necessary to prevent this lateral leakage. Sometimes the necessities of drilling lead to a satisfactory prevention. In sinking the well through the soil, sand, gravel, clay, or other loose material that may lie above the bed rock, it is customary to force down an iron tube, and sink it a few feet into the bed rock, by using a larger bit than that employed for the rest of the well. If a good joint is made here, and the rock below is tight, the lateral leakage may be thereby cut off, but this is not always available nor usually reliable. Besides, in many instances, the upper beds permit much waste, and recourse must be had to special methods for its control.

3. *Control of Flow.*—It is clear, upon consideration, that perfect control may be obtained by putting down a tube to the densest portion of the upper confining bed, if, by some device, the space surrounding it may be closed up, so that no water can rise outside of the tube. Formerly this was done by a very simple and ingenious device, known as the *seed-bag*. A long, stout leather bag is made in the form of a cylinder, open at both ends, and just the size of the well-bore. This is slipped on the lower end of the pipe, and the bottom of the bag securely fastened about the tube by wrapping with marline. A thimble just above the tie will aid in preventing slipping. It is then filled with dried flax-seed, and the upper end likewise closed around the tube. When thus adjusted, it is lowered into the well to the point determined upon, and supported there until the seeds swell by absorbing water. This enlarges the bag so as to fit the bore tightly and shut off all water from rising outside the pipe, and so all is compelled to ascend through the tube to the surface, or, at least, as high as the pressure is competent to force it.

A better and more convenient, but more expensive, packing takes advantage of the expansion of rubber disks when pressed together, instead of the swelling of flax-seed. A series of thick, washer-like rings of rubber are fitted about a section of pipe so adjusted between iron disks that, after being put down, they can be screwed together, and so caused to expand laterally, and completely fill the bore.

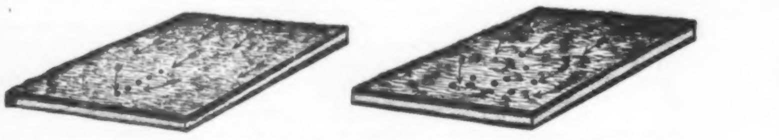
The construction of the parts and their adjustment are sufficiently indicated in the accompanying figures, which illustrate one of the forms in use.

In a form employed in the oil regions, the expansion of the rubber disks, or single cylindrical one, is accomplished by pressing a conical hollow wedge between the pipe and the rings, thus forcing them out against the walls of the well.

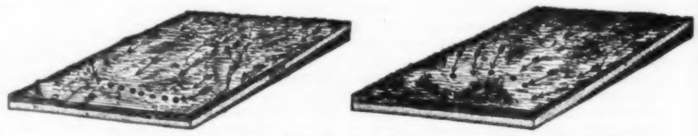
In this case the packing is supported by a perforated tube, an "anchor," reaching to the bottom of the well. As the packing in artesian wells is often located near the top, the necessity for support from below excludes this form in most cases.*

(*To be continued.*)

* This form is described and figured by Mr. Carll, Second Geol. Surv. Penn., Rep. on Oil Regions, iii., 1880, p. 322.



FIGS. 21 AND 22.—Tabular sections of strata, showing disadvantageous arrangements of wells.



FIGS. 23 and 24.—Tabular sections of strata, showing advantageous arrangements of wells.

ENTRANCE PORCH.

THE drawing illustrates the entrance porch of a large mansion at Weetwood, near Leeds, the residence of Mr. John Rawlinson Ford. The house, which is designed in English Renaissance of the 17th century, is picturesquely situated on the site of an old quarry, and commands extensive views of the surrounding country. It has been erected and recently completed from the designs and under the superintendence of Mr. William H. Thorp, A.R.I.B.A., of St. Andrew's Chambers, Park row, Leeds.—*Building News.*

SEA WALLS.

THE efficiency of the surface of a wall to resist the action of the waves obviously depends on two circumstances: first, the power with which the moving particles of the water act on the stones at the surface; and secondly, the force with which those stones resist removal. The object to be attained is to render the moving power of the water as small as possible and the resisting force of the stones as great as possible, relatively to each other. Without entering into the theory of waves, which involves the highest branches of mathematical analysis, it is sufficiently obvious to daily observation that the oscillation of each particle of water in a wave moving freely is partly vertical and partly horizontal; that when a sufficient depth of water exists in front of a wall or a line of cliffs, the mutual action of the direct and reflected waves produces a series of points of greatest agitation; and at those points the horizontal oscillation is either null or so small as compared with the vertical that practically the motion of the particles may be considered merely as an oscillation up and down. A vertical surface is, therefore, that which offers the least possible impediment to the natural motion of the particles of water under such circumstances, and upon which, consequently, they act with the least power; and a horizontal surface, being perpendicular to the motion of the particles, is that upon which they act with greatest power. It is also obvious that, when waves encounter a sloping bulwark, or a sloping beach, the vertical part of the oscillation is gradually converted, as the waves proceed, into an advancing and retreating oscillation parallel to the slope, that being the only direction in which the particles can move without destroying the surface of the beach or bulwark; and this oscillation has a powerful tendency to overturn and to remove any obstacle which projects above the line of the slope. Hence it is that large stones, extracted during storms from the seaward slopes of breakwaters, have frequently been swept entirely over to the landward side; and from the same cause it also arises that the coping and upper portions of a curved bulwark are liable to be overthrown, by the concussion of the body of water directed against them by the lower part of the slope. The force with which a stone resists removal is composed of three parts; the first arises from its own weight, and is obviously greater the flatter the slope, and is greatest of all when the surface is horizontal; the second arises from the pressure of the superincumbent masonry, and this is as obviously greater the steeper the slope, and greatest in a vertical wall; the third is the adhesion of the mortar or cement, and as this depends to a certain extent on the pressure from above, it also is greatest in a vertical wall.—*Prof. Rankine in the London Architect.*

STAMPED ENVELOPES.

SINCE the Government in 1851 began to sell stamped envelopes, there has been a steady increase in the amount required each year, until now the Government has for several years been selling more envelopes than all other producers combined.

Last year 279,000,000 stamped envelopes, worth $5,723,000, were sold. With every letting of the contract for furnishing these envelopes its size increases and the price of the envelopes is reduced. Envelopes which in 1869 cost $4.80 per 1,000 can now be had for $1.80 per 1,000, and the extra letter size that then cost $6 is now sold for $2.40.

TERRESTRIAL MAGNETISM.

AT a recent meeting of the Physical Society Professor W. Balfour Stewart, President, in the chair, the following communication was read: "On the Cause of the Solar Diurnal Variations of Terrestrial Magnetism," by Professor Balfour Stewart, LL.D., F.R.S. The author commenced by reviewing various theories that have been advanced to account for the solar diurnal inequalities of terrestrial magnetism. That they can be due to the direct magnetic action of the sun is highly improbable, since terrestrial analogies would lead us to infer that matter at the temperature of the sun is quite incapable of possessing magnetic properties, and also from the fact that changes in the range of the daily variation lag behind corresponding solar changes in point of time. The hypothesis of Faraday, that the observed variations are the result of the displacement of the magnetic lines of force due to the varying temperature, and consequently varying magnetic permeability, of the atmospheric oxygen, is disproved by the fact that there is no agreement between the chief magnetic variations and those of the temperature of the great mass of the atmosphere, though it is certain that there must be some effect due to this.

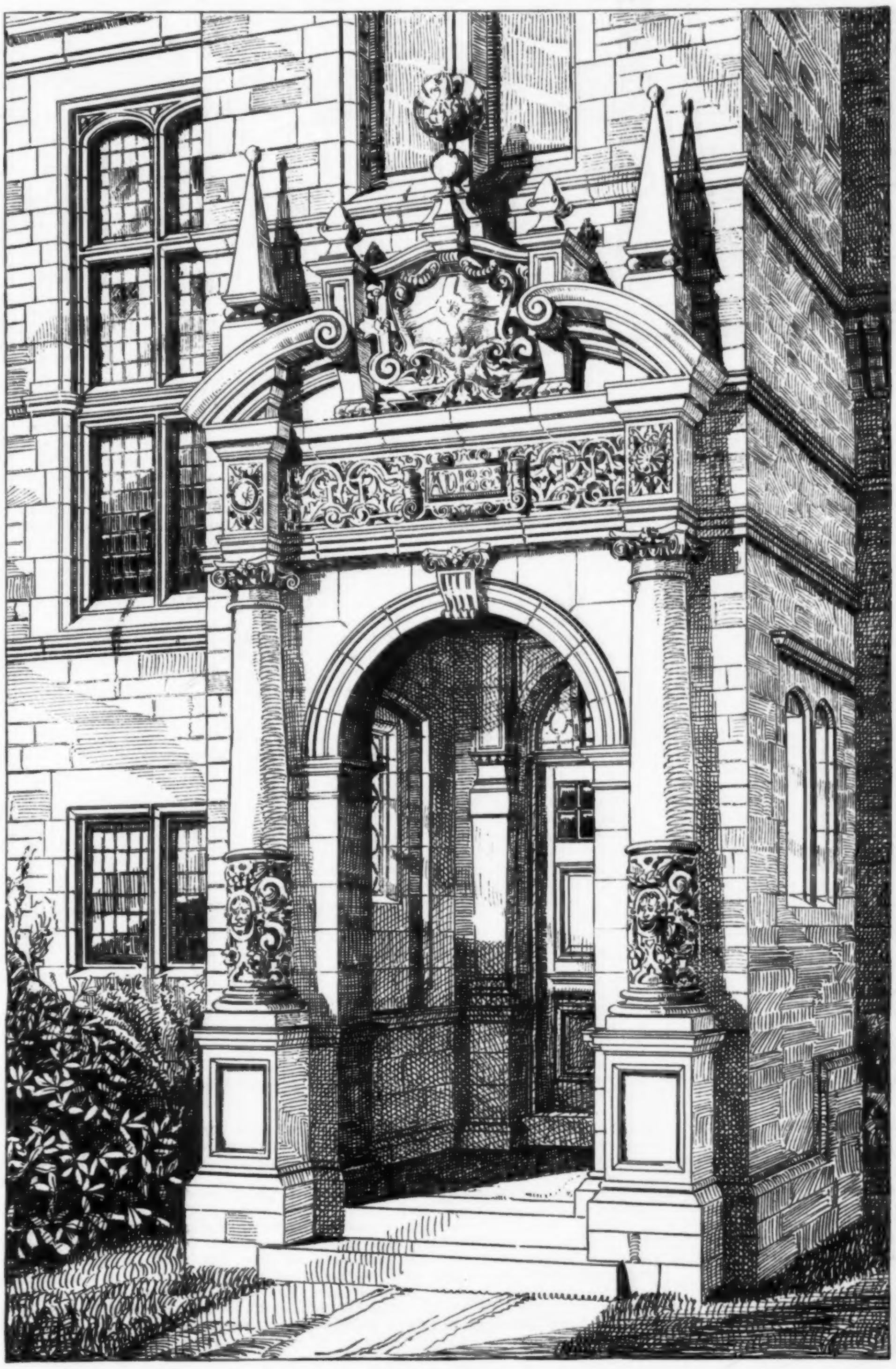
The earth-current hypothesis is quite unable to explain one of the chief characteristics of these variations—that they are half as great again at periods of maximum as at those of minimum sun-spot frequency. Sir George Airy has, moreover, been unable to detect any resemblance in form between the regular diurnal progress at the magnet and that of earth currents. We seem, therefore, compelled to seek for the cause of the variations in the upper atmospheric regions, and we cannot imagine such a cause to exist in any other form than that of a system of electrical currents. That currents may, and actually do, exist at great heights is shown by the aurora, which is unquestionably an electric current, and manifests a close connection with the phenomena of terrestrial magnetism. The great increase of magnetic variation at epochs of maximum sun spot frequency can also be accounted for ont his supposition. Professor Stokes has remarked that an increase in the radiating power of the sun would probably imply, not only an increase in general radiation, but a special and predominant increase in such actinic rays as are probably absorbed in the upper regions of the earth's atmosphere. These regions will, therefore, greedily absorb the new rays, their temperature will rise, and, as is known to be the case for gases, the electrical conductivity will be increased. Thus, even if we imagine the general atmospheric current to remain constant, a greater proportion of it would be thrown at such times into those heated portions which had become good conductors, but it is also probable that the current itself would be increased.

Assuming the existence of currents at great altitudes, the regularity and general characteristics of the diurnal variations would seem to point to a direct magnetic action of the currents rather than to any general induced change in the magnetic system of the earth, which to produce the observed results would have to be of a very artificial character. The diurnal variation of the declination attaining a westerly maximum at 2 P. M. north of the equator, and an easterly maximum at the same time south of it, would suggest the existence of currents flowing northward and southward from the equator to the poles, attaining a maximum in each hemisphere about two hours after the sun had passed the meridian. To supply this flow we should probably have to assume the existence of vertical currents ascending from the equatorial regions of the earth. At this point Dr. Schuster has endeavored to apply mathematical analysis to the subject. From the recorded observations at Greenwich, Lisbon, Hobarton, St. Helena, and the Cape he has shown that the work done by a magnetic pole describing a closed path in a horizontal plane at those places is equal to the work done upon it, and consequently no part of the ascending current can be inclosed by the path. Hence the potential at those places obeys the law expressed by the equation

$$\frac{d^2 v}{d x^2} + \frac{d^2 v}{d y^2} + \frac{d^2 v}{d z^2} = o.$$

From this Dr. Schuster has deduced two possible expressions for the potential, one referring to a system of currents above our heads, and the other to one beneath our feet. From the first of these expressions it follows that for latitudes greater than 45° the maximum of horizontal force should coincide with the minimum of vertical force, and *vice versa*, and this is actually the case at Greenwich, while the opposite should hold if the influencing system were beneath us. For latitudes below 45° the reverse of the above should be the case, and the observations at Bombay, though less decided than those at Greenwich, would seem to point the same way. On the whole, then, it must be said that the results of the first attempt are very encouraging, and point to the supposition that the greater part of the disturbing cause lies outside the earth's surface.

In a discussion that followed, Mr. Whipple remarked that recent observations in high latitudes seem to show that the aurora is not always at such a great height as is usually supposed. Professor A. W. Rucker cited the well-known case when an observer saw what appeared to be a meteor fall into the sun, while simultaneously, or nearly so, there was recorded a magnetic disturbance on the earth, as showing a direct solar action. Mr. Whipple, however, stated that he had recently examined this point, and believed that the very slight notch in the record, many similar to which have occurred since, was of an accidental nature, and a mere coincidence. Professor McLeod suggested that the earth current theory might be tested by observations at the bottom of a mine, where, according to the theory, the disturbances should be reversed. Professor Adams believed that there was nothing physically impossible in the existence of such currents as the author imagined.



DESIGN FOR AN ENTRANCE PORCH.

THE gauge of Southern railroads is to be changed on May 31 and June 1, from 5 feet to 4 feet 8½ inches, in order to conform to the standard of Northern and Western roads. It is stated that a total of over 13,000 miles of railway is embraced in the proposed change.

JAPANESE HOUSE BUILDING.*

By Professor EDWARD S. MORSE.

The first sight of a Japanese house—that is, a house of the people—is certainly disappointing. From the infinite variety and charming character of their various works of art, as we had seen them at home, we were anticipating new delights and surprises in the character of the house; nor were we on more intimate acquaintance to be disappointed. As an American, familiar with houses of certain types, with conditions among them signifying poverty and shiftlessness, and other conditions signifying refinement and wealth, we were not competent to judge the relative merits of a Japanese house.

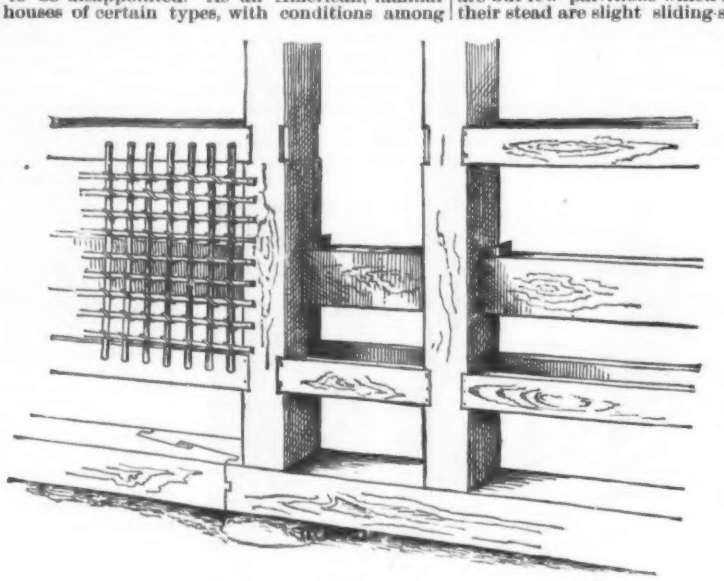


FIG. 1.—SIDE FRAMING.

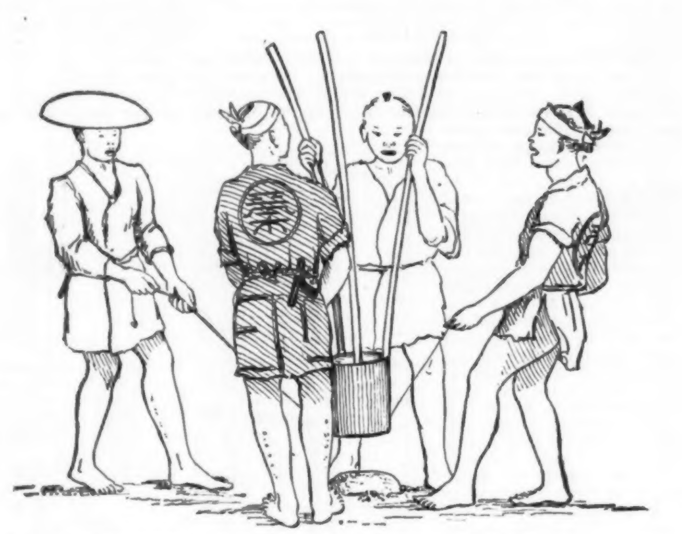


FIG. 2.—POUNDING DOWN FOUNDATION STONES.

The first sight, then, of a Japanese house is disappointing; it is unsubstantial in appearance, and there is a meagerness of color. Being unpainted, it suggests poverty; and this absence of paint, with the gray and often rain-stained color of the boards, leads one to compare it with similar unpainted buildings at home—and these are usually barns and sheds in the country, and the houses of the poorer people in the city. With one's eye accustomed to the bright contrasts of American houses, with their white, or light, painted surfaces; rectangular windows, black from the shadows within, with glints of light reflected from the glass; front door with its pretentious steps and portico; warm red chimneys surmounting all, and a general trimness of appearance outside, which is by no means always correlated with like conditions within—one is too apt at the outset to form a low estimate of a Japanese house. An American finds it difficult indeed to consider such a structure as a dwelling, when so many features are absent that go to make up a dwelling at home—no doors or windows such as he had been familiar with; no attic or cellar; no chimneys, and within no fireplace, and of course no customary mantel; no permanently inclosed rooms; and, as for furniture, no beds or tables, chairs or similar articles—at least, so it appears at first sight.

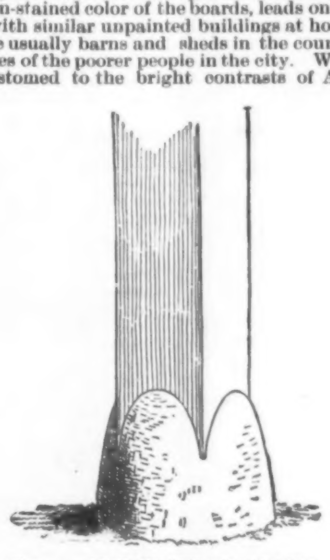


FIG. 3.—FOUNDATION STONE.

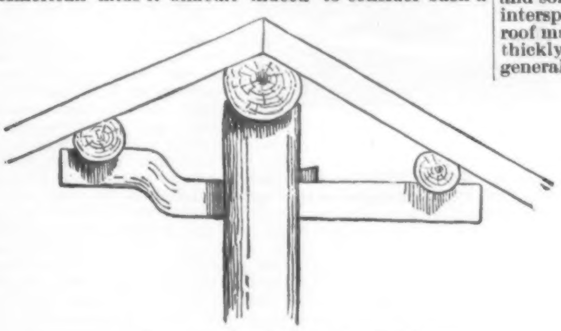


FIG. 4.—SECTION OF FRAMING.

One of the chief points of difference in a Japanese house, as compared with ours, lies in the treatment of partitions and outside walls. In our houses these are solid and permanent, and when the frame is built, the partitions form part of the framework. In the Japanese house, on the contrary, there are two or more sides that have no permanent walls. Within, also, there are but few partitions which have similar stability; in their stead are slight sliding-screens, which run in appropriate grooves in the floor and overhead. These grooves mark the limit of each room. The screens may be opened by sliding them back or they may be entirely removed, thus throwing a number of rooms into one great apartment. In the same way the whole side of a house may be flung open to sunlight and air. For communication between the rooms, therefore, swinging-doors are not necessary. As a substitute for windows, the outside screens, or *shoji*, are covered with white paper, allowing the light to be diffused through the house.

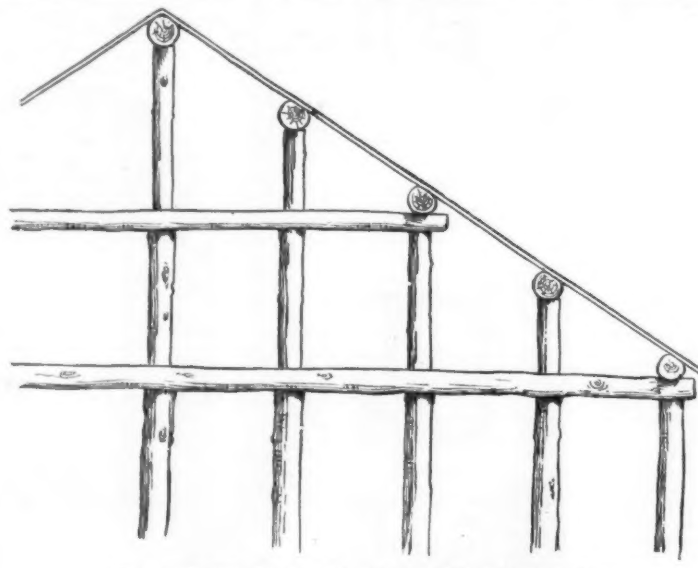


FIG. 5.—END FRAMING OF LARGE BUILDING.

Where external walls appear, they are of wood unpainted or painted black, and, if of plaster, white or dark slate colored. In certain classes of building the outside wall, to a height of several feet from the ground, and sometimes even the entire wall, may be tiled, the interspaces being pointed with white plaster. The roof may be either lightly shingled, heavily tiled, or thickly thatched. It has a moderate pitch, and, as a general thing, the slope is not so steep as in our roofs.

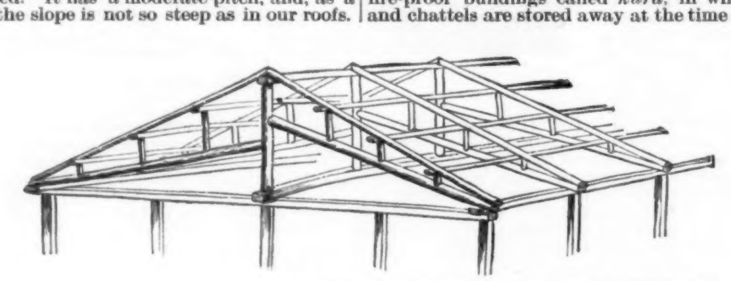


FIG. 6.—ROOF FRAME OF LARGE BUILDING.

Nearly all the houses have a veranda, which is protected by the widely overhanging eaves of the roof, or by a light supplementary roof projecting from beneath the eaves.

While most houses of the better class have a definite porch and vestibule, or *genka*, in houses of the poorer class this entrance is not separate from the living room; and, since the interior of the house is accessible from two or three sides, one may enter it from any point. The floor is raised a foot and a half or more from the ground, and is covered with thick straw mats, rectangular in shape, of uniform size, with sharp, square edges, and so closely fitted that the floor upon which they rest is completely hidden. The rooms are either square or rectangular, and are made with absolute reference to the number of mats they are to contain. With the exception of the guest-room, few rooms have projections or bays. In the guest-room, there is at one side a more or less deep recess divided into two bays by a slight partition; the one nearest the veranda is called the *tokonoma*. In this place hang one or more pictures, and upon its floor, which is slightly raised above the mats, rests a flower vase, incense burner, or some other object. The companion bay has shelves and a low closet. Other rooms also may have recesses to accommodate a case of drawers or shelves. Where closets and cupboards occur, they are finished with sliding screens instead of swinging-doors. In tea-houses of two stories, the stairs, which often ascend from the vicinity of the kitchen, have beneath them a closet, and this is usually closed by a swinging door.

In city houses the kitchen is at one side or corner of the house, generally in an L, covered with a pent roof. This apartment is often toward the street, its yard separated from other areas by a high fence. In the country the kitchen is nearly always under the main roof. In the city few outbuildings, such as sheds and barns, are seen. Accompanying the houses of the better class are solid, thick-walled, one or two storied, fire-proof buildings called *kura*, in which the goods and chattels are stored away at the time of a conflagration. These buildings, which are known to the foreigners as "godowns," have one or two small windows and one door, closed by thick and ponderous shutters. Such a building usually stands isolated from the dwelling, though often in juxtaposition; and sometimes, though rarely, it is used as a domicile.

In the gardens of the better classes, summer-houses and shelters of rustic appearance and diminutive proportions are often seen. Rustic arbors are also to be seen in the larger gardens. Specially constructed

* From "Japanese Homes and their Surroundings." By Edward S. Morse, Director of the Peabody Academy of Science; Late Professor of Zoology, University of Tokio, Japan; Member of the National Academy of Science; Fellow of the American Academy of Arts and Sciences, etc. With Illustrations by the Author. Boston: Ticknor & Co. 1886.

houses of quaint design and small size are not uncommon; in these the ceremonial tea-parties take place. High fences, either of board or bamboo, or solid walls of mud or tile with stone foundations, surround the house or inclose it from the street. Low rustic fences border the gardens in the suburbs. Gateways of various styles, some of imposing design, form the entrances; as a general thing, they are either rustic and light, or formal and massive.

Whatever is commonplace in the appearance of the house is toward the street, while the artistic and picturesque face is turned toward the garden, which may be at one side or in the rear of the house—usually in the rear. Within these plain and unpretentious houses there are often to be seen marvels of exquisite carving and the perfection of cabinet-work; and surprise follows surprise as one becomes more fully ac-

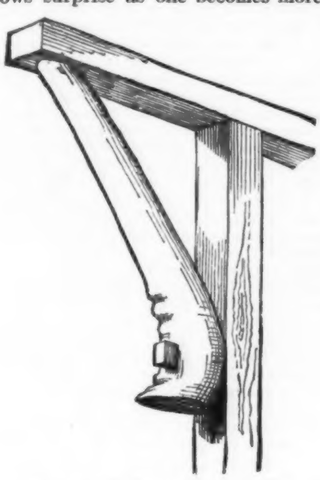


Fig. 7.—OUTSIDE BRACE.

quainted with the interior finish of these curious and remarkable dwellings.

The framework of an ordinary Japanese dwelling is simple and primitive in structure; it consists of a number of upright beams which run from the ground to the transverse beams and inclines of the roof above. The vertical framing is held together either by short strips, which are let into appropriate notches in the uprights to which the bamboo lathing is fixed, or by longer strips of wood, which pass through mortises in the uprights, and are firmly keyed or pinned into place (Fig. 1). In larger houses these uprights are held in position by a framework near the ground. There is no cellar or excavation beneath the house, nor is there a continuous stone foundation as with us. The uprights rest directly, and without attachment, upon single uncut or rough hewed stones, these in turn resting upon others, which have been solidly pounded into the earth by means of a huge wooden maul worked by a number of men (Fig. 2). In this way the house is perched upon these stones, with the floor elevated at least a foot and a half or two feet above the ground. In some cases the space between the uprights is boarded up; this is generally seen in Kioto houses. In others the wind has free play beneath; and, while this exposed condition renders the house much colder and more uncomfortable in winter, the inmates are never troubled by the noisome air of the

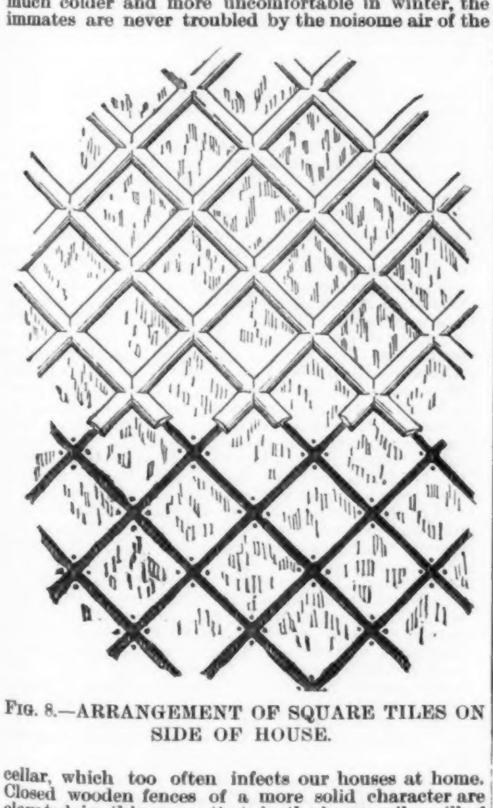


Fig. 8.—ARRANGEMENT OF SQUARE TILES ON SIDE OF HOUSE.

cellar, which too often infects our houses at home. Closed wooden fences of a more solid character are elevated in this way; that is, the lower rail or sill of the fence rests directly upon stones placed at intervals apart of six or eight feet. The ravages of numerous ground insects, as well as larvæ, and the excessive dampness of the ground at certain seasons of the year, render this method of building a necessity.

The accurate way in which the base of the uprights is wrought to fit the inequalities of the stones upon which they rest is worthy of notice. In the Emperor's garden we saw a two-storied house finished in the most simple and exquisite manner. It was, indeed, like a beautiful cabinet, though disfigured by a bright colored foreign carpet upon its lower floor. The uprights of this structure rested on large, oval, beach-worn stones buried endwise in the ground; and, upon the smooth rounded portions of the stones, which projected above the level of the ground to a height of ten inches or more, the uprights had been most accurately fitted (Fig. 3). The effect was extremely light and buoyant, though apparently insecure to the last degree; yet this building had not only withstood a number of earthquake-shocks, but also the strain of severe typhoons, which during the summer months sweep over Japan with such violence. If the building be very small, then the frame consists of four corner posts running to the roof. In dwellings having a frontage of two or more rooms, other uprights occur between the corner posts. As the rooms increase in number through the house, uprights come in the corners of the rooms, against which the sliding-screens, or *fusuma*, abut. The passage of these uprights through the room to the roof above gives a solid con-

Fig. 9.—STREET IN KANDA KU, TOKIO.

structive appearance to the house. When a house has a veranda—and nearly every house possesses this feature on one or more of its sides—another row of uprights starts in a line with the outer edge of the veranda. Unless the veranda be very long, an upright at each end is sufficient to support the supplementary roof which shelters it. These uprights support a cross beam, upon which the slight rafters of the supplementary roof rest. This cross beam is often a straight unhewed stick of timber, from which the bark has been removed. Indeed, most of the horizontal framing timbers, as well as the rafters, are usually unhewn—the rafters often having the bark on, or perhaps being accurately squared sticks; but, in either case, they are always visible as they project from the sides of the house, and run out to support the overhanging eaves. The larger beams and girders are but slightly hewed; and it is not unusual to see irregular-shaped beams worked into the construction of a frame, often for their quaint effects (Fig. 4), and in many cases as a matter of economy.

For a narrow house, if the roof be a gable, a central upright at each end of the building gives support to the ridge pole from which the rafters run to the eaves. If the building be wide, a transverse beam traverses the end of the building on a level with the eaves, supported at intervals by uprights from the ground; and upon this short uprights rest, supporting another transverse beam above, and often three or more tiers are carried nearly to the ridge. Upon these supports rest the horizontal beams which run parallel with the ridge-pole, and which are intended to give support to the rafters (Fig. 5).

In the case of a wide gable-roof there are many ways to support the frame, one of which is illustrated in the following outline (Fig. 6). Here a stout stick of timber runs from one end of the house to the other on a vertical line with the ridge-pole, and on a level with the eaves. This stick is always crowning, in order to give additional strength. A few thick uprights start from this to support the ridge-pole above; from these up-

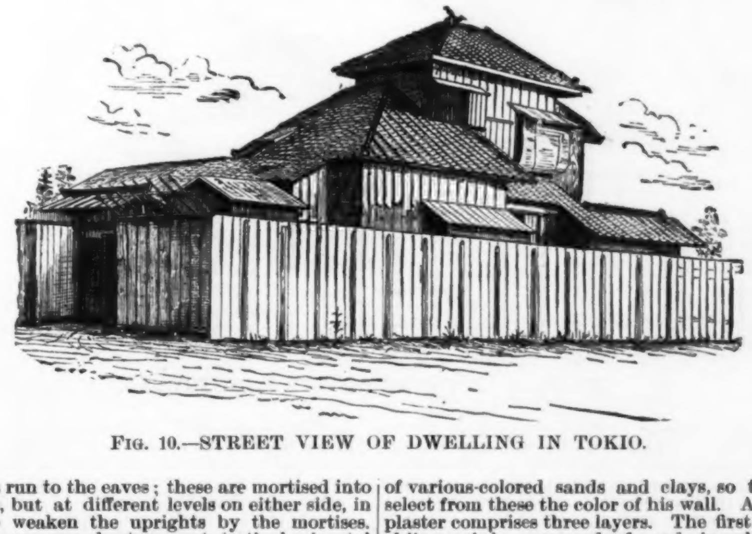


Fig. 10.—STREET VIEW OF DWELLING IN TOKIO.

rights beams run to the eaves; these are mortised into the uprights, but at different levels on either side, in order not to weaken the uprights by the mortises. From these beams run short supports to the horizontal rafters above.

The roof, if it be of tile or thatch, represents a massive weight—the tiles being thick and quite heavy, and always bedded in a thick layer of mud. The thatch, though not so heavy, often becomes so after a long rain. The roof-framing, consequently, has oftentimes to support a great weight; and, though in its structure looking weak, or at least primitive in design, yet experience must have taught the Japanese carpenters that their methods were not only the simplest and most economical, but that they answered all requirements. One is amazed to see how many firemen can gather upon such a roof without its yielding. I have seen massive house-roofs over two hundred years old, and other frame structures of a larger size and of far greater age, which presented no visible signs of weakness. Indeed, it is a very unusual sight to see a broken-backed roof in Japan.

Diagonal bracing in the framework of a building is never seen. Sometimes, however, the uprights in a weak frame are supported by braces running from the ground at an acute angle, and held in place by wooden pins. Outside diagonal braces are sometimes met with as an ornamental feature. In the province of Ise one often sees a brace or bracket made out of an unhewed piece of timber, generally the proximal portion of some big branch. This is fastened to an upright, and appears to be a brace to hold up the end of a horizontal beam that projects beyond the eaves. These braces, however, are not even notched into the upright, but held in place by square wooden pins, and are of little use as a support for the building, though answering well to hold fishing-rods and other long poles, which find here convenient lodgment (Fig. 7).

The framework of a building is often revealed in the room in a way that would delight the heart of an Eastlake. Irregularities in the form of a stick are not looked upon as a hindrance in the construction of a building. From the way such crooked beams are brought into use, one is led to believe that the builder prefers them. The desire for rustic effects leads to the selection of odd-shaped timber. Fig. 4 represents the end of a room, wherein is seen a crooked cross piece passing through a central upright, which sustains the ridge-pole.

As the rooms are made in sizes corresponding to the number of mats they are to contain, the beams, uprights, rafters, flooring-boards, boards for the ceiling, and all strips are got out in sizes to accommodate these various dimensions. The dimensions of the mats from one end of the empire to the other are approximately 3 feet wide and 6 feet long; and these are fitted compactly on the floor. The architect marks on his plan the number of mats each room is to contain—this number defining the size of the room; hence, the lumber used must be of definite lengths, and the carpenter is sure to find these lengths at the lumber yard. It follows from this that but little waste occurs in the construction of a Japanese house.

The permanent partitions within the house are made in various ways. In one method, bamboo strips of various lengths take the place of laths. Small bamboos are first nailed in a vertical position to the wooden strips, which are fastened from one upright to another; narrow strips of bamboo are then secured across these bamboos by means of coarse cords of straw, or bark fiber (Fig. 1). This partition is not unlike our own plaster-and-lath partition. Another kind of partition may be of boards; and against these small bamboo rods are nailed quite close together, and upon this the plaster is put. Considerable pains are taken as to the plastering. The plasterer brings to the house samples of various-colored sands and clays, so that one may select from these the color of his wall. A good coat of plaster comprises three layers. The first layer, called *shita-nuri*, is composed of mud, in which chopped straw is mixed; a second layer, called *chu-nuri*, of rough lime, mixed with mud; the third layer, called *uwa-nuri*, has the colored clay or sand mixed with lime—and this last layer is always applied by a skillful workman.

Many of the partitions between the rooms consist entirely of light sliding-screens. Often two or more sides of the house are composed entirely of these simple and frail devices. The outside permanent walls

of a house, if of wood, are made of thin boards nailed to the frame horizontally—as we lay clapboards on our houses. These may be more firmly held to the house by long strips nailed against the boards vertically. The boards may also be secured to the house vertically, and weather strips nailed over the seams—as is commonly the way with certain of our houses. In the southern provinces a rough house-wall is made of wide slabs of bark, placed vertically, and held in place by thin strips of bamboo nailed crosswise. This style is common among the poorer houses in Japan; and, indeed, in the better class of houses it is often used as an ornamental feature, placed at the height of a few feet from the ground.

Outside plastered walls are also very common, though not of a durable nature. This kind of wall is frequently seen in a dilapidated condition. In Japanese picture books this broken condition is often shown, with the bamboo slats exposed, as a suggestion of poverty.

In the cities the outside walls of more durable structures, such as warehouses, are not infrequently covered with square tiles, a board wall being first made, to which the tiles are secured by being nailed at their corners. These may be placed in diagonal or horizontal rows—in either case an interspace of a quarter of an inch being left between the tiles, and the seams closed with white plaster, spreading on each side to the width of an inch or more, and finished with a rounded surface. This work is done in a very tasteful and artistic manner, and the effect of the dark-gray tiles crossed by these white bars of plaster is very striking (Fig. 8).

The Japanese dwellings are always of wood, usually of one story, and unpainted. Rarely does a house strike one as being specially marked or better looking than its neighbors; more substantial, certainly, some of them are, and yet there is a sameness about them which becomes wearisome. Particularly is this the case with the long, uninteresting row of houses that border a village street; their picturesque roofs alone save them from becoming monotonous. A closer study, however, reveals some marked differences between the country and city houses, as well as between those of different provinces.

The country house, if anything more than a shelter from the elements, is larger and more substantial than the city house, and, with its ponderous thatched roof and elaborate ridge, is always picturesque. One sees much larger houses in the north—roofs of grand proportions and amplitude of space beneath that farther south occurs only under the roofs of temples. We speak now of the houses of the better classes, for the poor farm laborer and fisherman, as well as their prototypes in the city, possess houses that are little better than shanties, built, as a friend has forcibly expressed it, of "chips, paper, and straw." But even these huts, clustered together as they oftentimes are in the larger cities, are palatial in contrast to the shattered and filthy condition of a like class of tenements in many of the cities of Christian countries.

In traveling through the country, the absence of a middle class, as indicated by the dwellings, is painfully apparent. It is true that you pass, now and then, large, comfortable houses with their broad thatched roofs, showing evidences of wealth and abundance in the numerous *kura* and outbuildings surrounding them; but, where you find one of these, you pass hundreds which are barely more than shelters for their inmates, and, within, the few necessary articles render the evidences of poverty all the more apparent.

Though the people that inhabit such shelters are very poor, they appear contented and cheerful notwithstanding their poverty. Other classes, who, though not poverty-stricken, are yet poor in every sense of the word, occupy dwellings of the simplest character. Many of the dwellings are often diminutive in size; and, as one looks in at a tiny cottage containing two or three rooms at the most, the entire house hardly bigger than a good-sized room at home, and observes a family of three or four persons living quietly and in a cleanly manner in this limited space, he learns that in Japan, at least, poverty and constricted quarters are not always correlated with coarse manners, filth, and crime.

The accompanying sketch (Fig. 9) represents a group of houses bordering a street in Kanda Ku, Tokio. The windows are in some cases projecting or hanging bays, and are barred with bamboo or square bars of wood. A sliding-screen, covered with stout white paper, takes the place of our glass-windows. Through these gratings the inmates of the house do their bargaining with the street venders. The entrance to these houses is usually by means of a gate, common to a number. This entrance consists of a large gate used for vehicles and heavy loads, and by the side of this is a smaller gate used by the people. Sometimes the big gate has a large square opening in it, closed by a sliding-door or grating—and through this the inmates have ingress and egress.

The houses, if of wood, are painted black; or else, as is more usually the case, the wood is left in its natural state, and this gradually turns to a darker shade by exposure. When painted, a dead black is used; and this color is certainly agreeable to the eyes, though the heat-rays caused by this black surface become almost unendurable on hot days, and must add greatly to the heat and discomfort within the house. With a plastered outside wall the surface is often left white, while the framework of the building is painted black—and this treatment gives it a decidedly funereal aspect.

The sketch shown in Fig. 10 is a city house of one of the better classes. The house stands on a new street, and the lot on one side is vacant; nevertheless, the house is surrounded on all sides by a high board-fence—since, with the open character of a Japanese house, privacy, if desired, can be secured only by high fences or thick hedges. The house is shown as it appears from the street. The front door is near the gate, which is shown on the left of the sketch. There is here no display of an architectural front; indeed, there is no display anywhere. The largest and best rooms are in the back of the house; and what might be called a back-yard, upon which the kitchen opens, is parallel with the area in front of the main entrance to the house, and separated from it by a high fence. The second story contains one room, and this may be regarded as a guest-chamber. Access to this chamber is by means of a steep flight of steps, made out of thick plank, and unguarded by hand-rail of any kind. The roof is heavily tiled, while the walls of the house are outwardly composed of broad thin boards put on vertically, and having strips of wood to cover the joints. A back view of this house is shown in Fig. 11. Here all the rooms open directly on the garden. Along the veranda are three rooms *en suite*. The balcony of the second story is covered by a light supplementary roof, from which hangs a bamboo screen to shade the room from the sun's rays. Similar screens are also seen hanging below.

FIG. 11.—VIEW OF DWELLING FROM GARDEN IN TOKIO.

The veranda is quite spacious; and in line with the division between the rooms is a groove for the adjustment of a wooden screen or shutter when it is desired to separate the house into two portions temporarily. At the end of the veranda, to the left of the sketch, is the latrine. The house is quite open beneath, and the air has free circulation.

The country house of an independent *samurai*, or rich farmer, is large, roomy, and thoroughly comfortable. I recall with the keenest pleasure the delightful days enjoyed under the roof of one of these typical mansions in Kabutoyama, in the western part of the province of Musashi. The residence consisted of a group of buildings shut in from the road by a high wall. Passing through a ponderous gateway, one enters a spacious court-yard, flanked on either side by long, low buildings, used as store-houses and servants' quarters. At the farther end of the yard, and facing the entrance, was a comfortable old farm-house, having a projecting gable-wing to its right (Fig. 12). The roof was a thatched one of unusual thickness. At the end of the wing was a triangular latticed opening, from which thin blue wreaths of smoke were curling. This building contained a few rooms, including an unusually spacious kitchen. The kitchen opened directly into a larger and unfinished portion of the house, having the earth for its floor, and used as a wood-shed. The owner informed me that the farmhouse was nearly three hundred years old. To the left of the building was a high wooden fence, and, passing through a gateway, one came into a smaller yard and garden. In this area was another house quite independent of the farmhouse; this was the house for guests. Its conspicuous feature consisted of a newly thatched roof, surmounted by an elaborate and picturesque ridge—its design derived from temple architecture. Within were two large rooms opening upon a narrow veranda. These rooms were unusually high in stud, and the mats and all the appointments were most scrupulously clean. Communication with the old house was by means of a covered passage. Back of this dwelling, and some distance from it, was still another house, two stories in height, and built in the most perfect taste; and here lived the grandfather of the family—a fine old gentleman, dignified and courtly in his manners.—*Popular Science Monthly.*

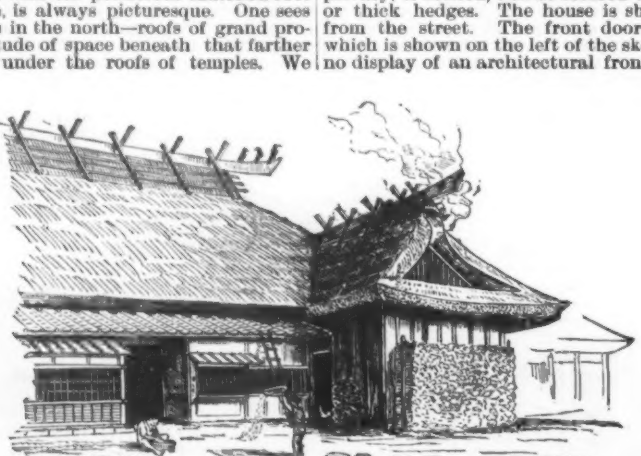


FIG. 12.—OLD FARMHOUSE IN KABUTOYAMA.

THE ANCIENT CITIES OF CHALDEA.

MR. W. ST. CHAD BOSCAWEN lately delivered at the British Museum lectures on the "History and Antiquities of Ancient Assyria and Chaldea," the subject being Babylon as a City of Temples. Mr. Boscawen remarked that Babylon was one of the ancient cities of Mesopotamia, round whose ruins tradition had always lingered, and upon whose site the name of Babel had always found a representative. In both Hebrew and Arabic tradition, writers have located the ancient city of Nimrod in the group of mounds to the northeast of Chaldea, the chief of which bore the name of Babel. The lecturer narrated the descriptions of the site given by some of the earlier writers, chief among whom were the Jewish traveler Benjamin of Tudela, who visited the ruins in 1165, and the English traveler John Eldred. The first European traveler who made known the features of the ruins of Babylon was Claudius Rich, the English resident at Bagdad, who in the early part of the present century visited and described the site in a memoir full of most valuable topographical details. Mr. Boscawen then proceeded to describe the chief features of the site, the remains of the city walls and gates, and the Babel Kasr, and Mujelibe mounds, and to show how these tended to curtail the extravagant accounts of the Greek writers. It was to Mr. Rassam that the merit belonged of the first discoveries that enabled us to locate some of the chief edifices, and thus to gain a starting point in the reconstruction of the topography of the ancient city. By his explorations in 1880 he had shown that the Babel mound was the site of the palace to which the Bhugong Gardens were attached, the discovery being confirmed by the traces of extensive hydraulic works. A slab found on the Kasr mound marked it as the site of the palace, as it bore the inscription, "The Palace of Nebuchadnezzar;" while the Mujelibe mound was the spot on which the chief government offices were placed, as it was here that the celebrated Egibi tablets were found. The lecturer proceeded then to consider the ancient names of the city as found in the inscriptions. The earliest and most important was the Akkadian form Ka-Dimmira, "The gate of God." .nis name, both in its Semitic and non-Semitic form, ıs found on the earliest bricks, and its etymology is so clear that the explanation given in Genesis, as meaning "confusion," was no longer tenable. On a small tablet there was recorded, though in a mutilated form, the tradition that the Babylonians, under a wicked king, rebelled against the gods and built a tower. As fast as they built the gods overthrew, and at last, to impede the work, they determined to "confound their speech." Mr. Boscawen next dealt with the inscriptions relating to the shrine of Bel, the temple of Belus in Babylon. The records of repairs of this temple were numerous. One of the earliest of these was one of the King Khammurabi, dating from about the time of the Abramic migration, which recorded the erection of the holy place of the god. There was in existence an inscription which gave the dimensions of every shrine in the temple, and from which the lecturer had been able to reconstruct a plan of the great temple. Mr. Boscawen concluded with a *résumé* of the history of the temple during the Persian and Greek periods of rule.

WINKING PHOTOGRAPHS.

WINKING photographs are said to be produced in the following manner: One negative is taken with the sitter's eyes open; another without change of position, with the eyes shut. The two negatives are printed on opposite sides of the paper, "registering" exactly. Held before a flickering lamp, or other variable source of light, the combined photographs show rapid alternations of closed and open eyes, the effect being that of rapid winking.

TRICKS WITH VEGETABLES.

JOHN R. CORYELL.

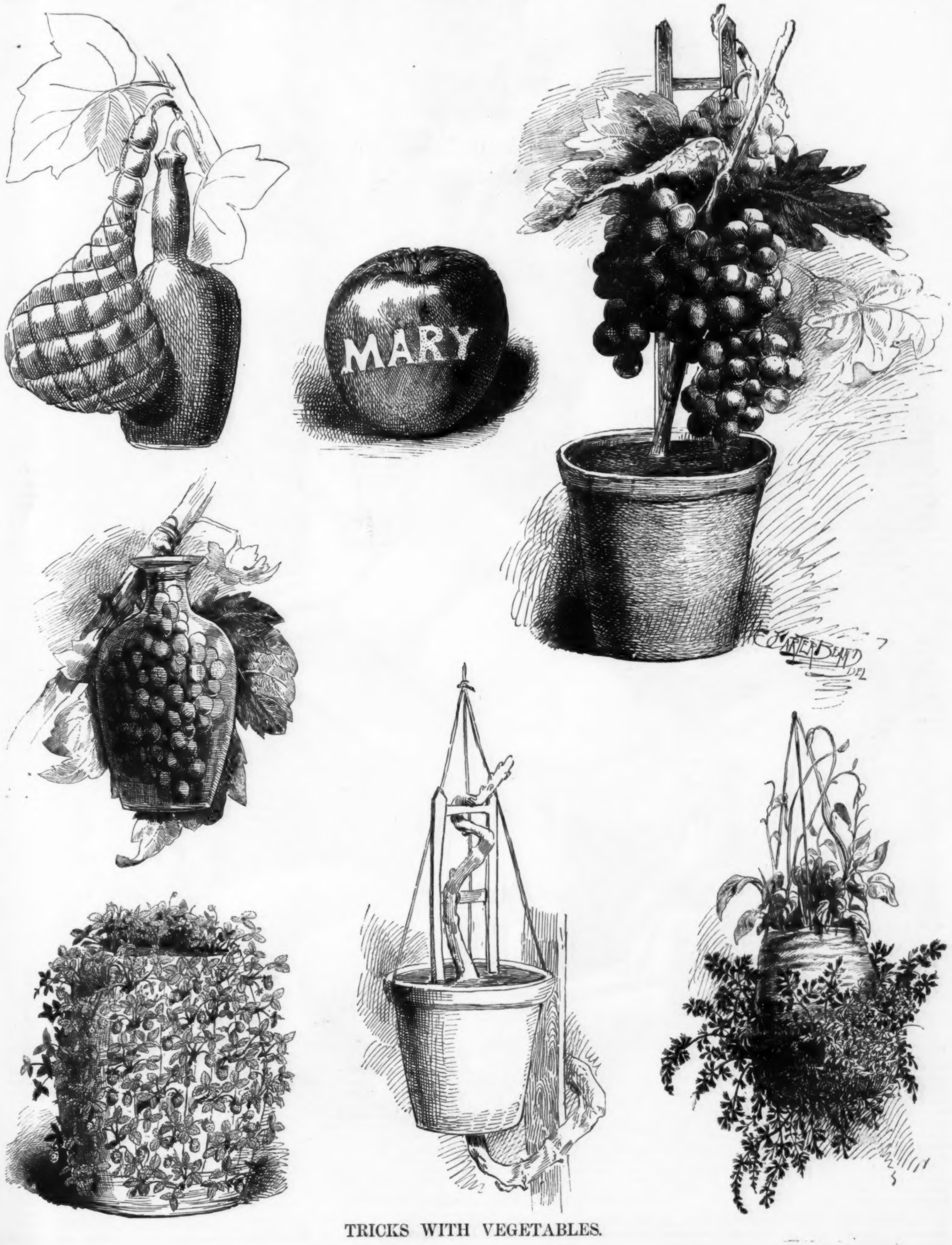
THE extraordinary adaptability of growing plants to the circumstances of their environment is constantly exemplified, not only in singular accidental forms, but in a great variety of carefully designed ways practiced by the florist or horticulturist, either for purposes of effect or convenience. Illustrative of what may be called this docility of plant life, are a series of experiments, some of them sufficiently fantastic to fairly come under the head of "tricks."

No better subject for experiments of this sort can be found than any one of the large family of gourds. The best success will, of course, be had with the shapes which are naturally nearest the one desired to be produced, but with a little care forms may be produced which are as far as possible from those naturally assumed by the gourd. All that is required is to confine the gourd, as soon as may be, in a mould of the desired form, and the yielding fruit will without a struggle adapt itself to it. For example, if the shape of a Florence flask be desired, the gourd should be placed in the flask and secured there by cords being tied from the neck of the flask to the vine. As soon as the gourd has completely filled the mould, it should be taken from the vine to check further growth, and the mould should then be broken. If an irregular shape is desired, the experimenter may exercise his ingenuity, and will discover then how singularly plastic the growing gourd is.

Causing a name to grow upon an apple, pear, peach, or other fruit is a trick interesting in itself, a wonder to children, and a joy to those young persons who are described as in the "tender time of life." It is accomplished by cutting tinfoil, or any similar substance, into the desired letters and placing them on the fruit. The air and sunlight being thus kept from the fruit under the tinfoil, it will be of a distinct color.

To grow a bunch of grapes in a bottle, the neck of which is too small to receive even one grape, is an easy thing to do, but always causes great wonderment in persons who see only the result. As soon as the grapes are set on the bunch, the bottle should be slipped over the bunch and tied securely. Care must be taken to keep water out of the bottle, else the grapes will be likely to rot. Nothing more is necessary to be done, as the grapes will grow as well in the bottle as out of it.

To have a bunch of grapes growing on a vine in a flower pot requires some care, but is not really difficult. The part of a vine upon which a thrifty bunch of



TRICKS WITH VEGETABLES.

LAPDOGS. Drawn from life by Jean Bungart.

1. Maltese Dog. 2. Rough-coated Terrier. 3. Blenheim Spaniel. 4. King-Charles. 5. Pug. 6. Smooth-coated Terrier. 7. Silky Spitz. 8. Silky Poodle. 9. South American Hairless Dog. 10. Greyhound. 11. Yorkshire Terrier. 12. Skye Terrier.

grapes has started is put through the hole in the bottom of a flower pot, and drawn up until a reasonable length of vine extends beyond the rim. The pot is secured in position, and rich earth filled into it around the vine. After a time the vine in the pot will take root, and by the time the grapes are ready to ripen, the vine can be removed at the bottom of the pot without injury to the grapes, which will go on ripening. When successfully done, a very beautiful effect is produced, and nothing daintier as a gift for an invalid can be imagined.

Another very effective result is obtained by growing a strawberry plant in a carrot. Take as large a carrot as can be had, and scoop out the large end to form the receptacle for the earth in which the strawberry plant is to be grown. The earth used cannot be too rich, and it will be well to keep it moist, not wet, with some sort of liquid manure. Select a young, thrifty plant, and, first half-filling the hole in the carrot, place the plant in the hole with roots well spread. Then fill in the hole with earth until the crown of the plant is reached. The earth should be carefully pressed about the roots, and two or more holes should be made through the carrot in such a way as to drain the earth receptacle. The carrot may then be hung up in a warm place, and not only will the strawberry grow and bear its beautiful fruit, but the carrot too will throw out a beautiful green foliage, thus making a very pretty combination of colors. This can also be done with a sweet potato, as shown in illustration.

Another unique plan for growing strawberries is to fill a barrel with rich earth, first, however, boring a number of holes with an auger in the sides of the barrel. In each hole plant a strawberry vine, and in the course of time the barrel will be covered with green foliage, against which will grow the luscious red berries.

LAPDOGS.

LILIPUTIANS among dogs were acknowledged favorites with women even in the times of the Greeks and Romans, as they are now; but sometimes dogs of one class are in fashion and sometimes dogs of another class. Many of the different breeds have died out, and others have degenerated.

In the time of King Charles II. of England, the King Charles spaniel (Fig. 4 in the group shown in the opposite cut) and the Blenheim spaniel were great favorites, not only with ladies, but gentlemen also vied with each other in the acquisition of as many and as small specimens of these little dogs as possible, and they even went so far as to carry their pets about with them. Of late years these dogs have again come into vogue. The pug (Fig. 5), which has always played an important part as constant companion for old bachelors and foot warmer for old maids, has for a long time been neglected, but now he is so successfully bred that good specimens can be had at a low price.

In addition to these aristocrats, we will mention two breeds which are purely German; the first is the droll little rough-coated terrier (Fig. 2), with its wise eyes shaded by silky hair, and comical and affectionate ways; and the second, the smooth-coated terrier (Fig. 6), pure specimens of which, however, are seldom found. The silky poodle (Fig. 8) is a descendant, or rather a miniature edition, of the larger poodle. The silky spitz (Fig. 7) disappeared for a time, but it is now raised with great care, and is one of the most, if not the most, attractive of small dogs. He is covered with smooth, white, silky hair, and from under this beautiful coat the wise dark eyes and the little black nose peep out; the mouse-like ears and the delicately shaped limbs help to give him a very elegant appearance.

The English Yorkshire terrier (Fig. 11) is one of the most valuable of dogs, and is seen at all dog shows, where he generally lies stretched out on a silk cushion in a glass case. He is of low build, and the beautiful glossy, silver-gray hair on his body and soft golden hair on his head and legs give him a peculiar appearance. His hair is so long that it touches the ground, and completely covers his eyes and feet. The Skye terrier (Fig. 12) is not as elegant as the Yorkshire terrier. Its principal color is a mixed gray (so-called pepper and salt), and though its hair falls over its eyes, it does not cover them completely. His ears are large, and his head is rather heavy in proportion to the rest of his body.

The oldest of the dwarf dogs is the Maltese dog (Fig. 1), for he was mentioned in the time of Aristotle, when he was fondled by Greek beauties. The delicate greyhound (Fig. 10) with his light, springy motions, was the especial favorite of Frederick the Great. This animal has a delicate constitution, and seems to be always shivering; he is, therefore, generally kept covered. A less highly prized class is that of the hairless dogs (Fig. 9), natives of South America, the rarest specimens of which are spotted, and have bunches of hair on their heads and the ends of their tails.

The long-haired dogs require, of course, a great deal of care, daily brushing and, in warm weather, frequent baths being absolutely necessary. Dainties, and specially cake, are forbidden luxuries, milk porridge with bread or meat broth with vegetables and without seasoning being the best food for small dogs. This food with the addition of a pinch of magnesia and sulphur will keep the blood pure, and will prevent skin disease.—*Illustrirte Zeitung.*

GEOLOGY OF NATURAL GAS.

By CHAS. A. ASHBURNER.

THE general geological conditions upon which the occurrence of natural gas seems to depend, from a consideration of the facts at present at our command, are: (1) The porosity and homogeneousness of the sandstone which serves as a reservoir to hold the gas. (2) The extent to which the strata above or below the gas sand are cracked. (3) The dip of the gas sand and the position of the anticlinals and synclinals. (4) The relative proportion of water, oil, and gas contained in the gas sand. And (5) the pressure under which the gas exists before being tapped by wells. Other conditions may still be discovered which will have as important a bearing upon the problem as these which I have stated.

The oil and gas regions of Pennsylvania are one in a geological sense. The strata drilled through by the gas wells in the vicinity of Pittsburg (now considered the most important gas district) are, in a general way, the same as the strata in the different parts of the Devonian and Carboniferous series pierced by the oil wells in all the oil pools from Alleghany County, New York, southwest to Washington County, Pennsylvania.

1. The first necessary condition for the presence of gas, however, is dependent upon the existence of a porous rock to serve as a reservoir to hold it. A number of wells have been drilled which have found gas, but, if the drillers' records are to be credited, have not pierced sand beds; in these cases the gas has been unquestionably obtained from a crack in the strata which serve as a conduit to convey the gas from its sand-bed reservoir to the well.

2. The origin of natural gas has an important bearing upon its economic geology. Although it is believed that we are in possession of much data to throw some light upon this interesting question of cause, yet it is still shrouded in too much uncertainty to permit of complete explanation. It is necessary, however, that some statement should be made in regard to the origin of gas in order to thoroughly comprehend the conditions upon which its existence seems to depend. It would appear that the gas is closely related to petroleum, and that their origin is due largely to the same cause—the decomposition of animal and vegetable life. It is believed that the gas is not indigenous to the sand rock from which it is obtained, but comes from the decomposition of life forms which were entrapped in underlying strata. If this be so, the amount of gas contained in any one sand depends, first, upon the extent to which the rocks are cracked between the horizons of such organic remains and the gas-sand reservoir, in order to permit the gas to flow into the sand; and, second, upon the extent to which the rocks are cracked above the gas sand, which would permit the gas to escape into the atmosphere and totally disappear.

That the absence of both petroleum and natural gas in our plicated strata east of the oil regions is to be explained by the cracking of the rocks would seem to be evident, since the survey of the outcropping rocks and a study of the records of dry wells show that the oil and gas sands extend far beyond the limits of the area of the region in which any traces of oil or gas have ever been found. Even within the area where oil and gas wells have been found, the cracking or jointing of the rocks must have a potent influence upon the amount of oil or gas obtained in certain localities.

3. The general structural geology of the oil and gas regions is comparatively simple. The rocks lie nearly horizontal, being thrown into broad and almost imperceptible rolls by southwest-dipping anticlines and synclines which are parallel, in a general way, to the escarpment of the Alleghany Mountains, and which produce gentle northwest and southwest dips from the crests of the anticlines down toward the centers of the synclines. An appreciation of the intensity of these dips may be had from the following figures: From the city of Bradford, in McKean County, immediately south of the Pennsylvania and New York State line, and about 72 miles in an air line a little south of east of the city of Erie, the strata dip at an average rate of 14 feet per mile to Oil City, which is 64 miles south 55° west of Bradford. From Oil City to Pittsburg, a distance of 70 miles in a direction south 12° west, the average rate of dip per mile is about 20 feet. From the city of Erie to Beaver, on the Ohio River, at the mouth of the Shenango River, the distance is about 100 miles in a direction south 7° west, and the average rate of the fall of the strata is 20 feet per mile. Although these are the general dips of the rocks, yet many very much greater local dips occur in the areas between the localites named.

The maximum dip in the Bradford oil region, which I determined from my surveys in 1879, was 69 feet per mile, and this for a distance of only 2½ miles. In the Venango oil belt and southern end of the Butler oil belt the dip of the oil sands, as shown by Mr. Carll's survey, rarely exceeds 35 feet per mile. A dip in the strata at the rate of 75 to 100 feet per mile, for even very short distances, is the rarest occurrence.

Although the dip of the gas sand and position of the anticlines and synclines have an important bearing upon the occurrence of gas (in many cases this would seem to be the most important consideration), yet it is not believed that natural gas wells can be located independently on what has been formulated as "the anticlinal theory," since all great gas wells are not found along anticlinal axes, although some of the largest and most important wells in Pennsylvania have been found in such positions. A great many wells have been drilled in synclines which have found gas. These two statements are of great importance, since a large amount of money is now being expended in drilling wells which have been located on the basis of the anticlinal theory, so called.

In a paper which I read before the American Institute of Mining Engineers in September, 1884, on the geology of natural gas, I cited a number of cases where large gas wells have been found on monoclinal slopes or in synclinals far removed from any anticlinal axes.

Mr. John F. Carll, assistant geologist in charge of the Survey of the Oil and Gas Region, in referring to the Murraysville district, and to the Bear Valley and Pine Run wells, about nine miles northeast of the village of Murraysville, says in his forthcoming report of progress for 1885, now going through the press:

"Here we have a good illustration of the uncertainties that must ever attend all operations for oil and gas. A large gas well (Beaver Valley) on an anticlinal, in the Murraysville-Leechburg sand; a good gas well (Pine Run) in a synclinal, where the Freeport upper coal is found 210 feet lower than at Beaver Valley well, but in a sand 125 feet deeper than the Leechburg sand; a dry hole on the anticlinal with no available gas in either of the gas horizons of the upper wells, and all within a radius of less than two miles."

Making special reference to the anticlinal theory, Mr. Carll says:

"*The anticlinal theory*—that gas wells should always be located on anticlinals, and not in synclinals, because gas is lighter than water or oil, and should seek the highest reservoirs—premises a permeable sand rock containing water, oil, and gas, or only water and gas, in such proportions, and under such conditions, that the fluids may stratify themselves as freely and completely as they would do in an open tank under air, the water and oil at the lower levels and gas at the higher.

"There is nothing new in the theory, as many suppose, for it has been long ago discussed and illustrated in text books on geology and in nearly every book published relating to the production of petroleum. Well locators, however, gave it but little attention until developments intended exclusively for natural gas commenced.

"Wherever the proper conditions exist, there seems to be no objection to accepting an anticlinal as one of the factors in locating gas wells; but, in most cases, it is being too inconsiderately used, without giving due thought to other and much more important considerations.

"First, it is proved by the experiences of over twenty-five years that no profitable oil or gas well can be obtained in the upper Devonian strata and rocks of later ages in the Pennsylvania oil fields unless a good sand-rock reservoir is found. Second, it is a generally accepted conclusion that the oil and gas-making material was deposited before—and, perhaps, in some cases, with—the producing sand rock, not after it; that the tendency of gas and oil when generated is upward, not downward. Therefore, the two primary conditions to be sought are gas-producing materials and sand-rock reservoirs to hold the products. All others are secondary, for, without these, no profitable oil or gas wells can be had.

"Now, what has an anticlinal to do with these indispensable qualifications? Evidently nothing, in a primary sense, for it had no existence when they were being prepared. Nevertheless, I have heard experienced operators, self-confident in their geological acquirements, assert that certain oil fields could not extend beyond fixed limits on account of anticlinals which interrupted the deposition of the oil sands when they were forming.

"It is well known that all our oil rocks are sedimentary; that they are composed of materials derived from older rocks, the disintegrated particles of which have been sifted, assorted, and deposited in stratified layers by the action of water. These rocks are known to be several thousand feet in thickness, and untold ages elapsed while they were forming. For the purposes of this discussion, we need go no farther back in the eons of the past than the time when the Murraysville gas sand (taking a definite stratum to avoid confusion) was completed by those changes of conditions—whatever they were—which terminated the sand deposits at that spot and commenced to lay down the overlying shales.

"At that date the two most important requisites for a future gas field had been provided. The gas-making material had been deposited; the receiving tank, so to speak, put in place, and the impervious cover was being put on. But the sedimentary deposits were not yet completed. Other carbonaceous shales, other sand rocks, alternating with beds of coal, slates, fire clays, and limestones, were yet to be superimposed to a height of 3,000 feet or more. These all were deposited in the course of time in regularly stratified layers, showing that no deep-seated, unequal, or local disturbance had occurred up to the date of their completion. Subsequently some great change took place. The whole region was lifted above ocean level; the Alleghany Mountains rose in crested ridges, and the Murraysville anticlinal with other comparatively minor flexures, was formed.

"Now, what effect could these anticlinal movements have had upon gas-producing capabilities of the rocks at Murraysville, where, as we have seen, the gas materials and the reservoirs had been provided ages before. Had the hydrocarbons stored in the shales lain dormant all these ages awaiting some awakening energy to set them free, which could only be furnished by the crash and pressure accompanying anticlinal movements? This can hardly be admitted, for oil and gas are plentifully found in regions where the rocks have not been so affected. Did the anticlinal movement open up crevices below the gas sand leading down to some deep-seated storehouse of gas beneath the sedimentary rocks? This question is open to the same objection as the former one; and, furthermore, is it not reasonable to suppose that the side thrust and pressure which caused these anticlinals to rise would have a tendency to consolidate the basal shales confined under a heavy mass of incumbent strata, and to fracture and loosen the rocks near the surface if anywhere? It is probable that gas, after forcing its way up through thousands of feet of clay shales and slates, such as have been penetrated by wells to the depth of at least 1,800 feet without encountering any noticeable leads, would stop in the gas sand; only checked by a covering of a few feet of clay shale overlain mostly by sandstone to the surface.

"If, then, anticlinals had no part in depositing the gas-making materials, and sand-bed reservoirs were not the special agents that caused the generation of gas to commence, and the anticlinals did not open crevices to deep-seated sources of unlimited supplies, what other favorable conditions could there have been instrumental in rendering the anticlinals more prolific in gas now than any other locality? I can imagine but one, which is this: When the anticlinal uplift tilted and warped the previously horizontal strata, destroying the equilibrium of the fluids in them, a new adjustment of their positions in the sand beds followed. This readjustment, in cases where all the conditions were favorable, probably resulted in storing larger quantities of gas in the anticlinals than elsewhere; but we have no assurance that all the arches were thus fortunately circumstanced, or that the conditions making one part of an arch productive would be equally efficient in another part.

"If the sand rocks were continuous, instead of being in chains of beds or pools, and sufficiently porous to allow fluids to circulate through long distances—say, for instance, from the southerly part of the Butler oil belt at Herman Station to Murraysville—then, according to the principles upon which the anticlinal theory is founded, the Murraysville rock should now be deluged by water, while the Herman Station rock should be stored with gas, for the monoclinal slope of 22 feet to the mile would submerge the anticlinal at Murraysville, where the gas sand on the crown of the arch is more than 200 feet lower than it is at Herman Station.

"In applying the anticlinal theory to locating gas wells, this great monoclinal slope has, in most cases, been lost sight of by those who do not understand the geological structure of the country. Knowing the tendency of gas to seek the higher levels, and only

stopping to learn that an anticlinal is an arch in the rocks, they procure a geological report, trace out the anticlinal referred to, secure leases upon it, as they suppose, and drill wells. If no gas is obtained, the survey is charged with not having located the anticlinals correctly. They overlook the fact that the crests of anticlinals slope with the progressive dips of all the rocks toward the southwest, and that this has an important bearing upon the question of anticlinal reservoirs. For example, the Brady's Bend arch is 450 feet lower at the Ohio River than it is at Lardintown, Butler county; the Murraysville axis is 250 feet lower where it crosses the Pennsylvania Railroad than at Murraysville. Now, if the whole country between Lardintown and the Ohio is underlain by a permeable sandstone containing water and gas, and which produces gas at Lardintown, on the crown of the arch, and water on its flanks (in the synclinals), say 225 feet below its crest, then, if the fluids are free to seek natural levels, water would cross the anticlinal's crest half-way between Lardintown and the Ohio (for there the crest has fallen 225 feet, which puts it on a level with the watered synclinal at Lardintown); and going southwesterly from that point the anticlinal must be as thoroughly waterlogged as the synclinals. Hence, this universally prevailing monoclinal dip is quite as important a factor in locating gas wells as the anticlinals are, for while the former affects the whole country, the latter only favorably affect local areas.

"As before stated, the productive sand rocks of the oil regions are generally deposited in elongated beds, stretching out in a northeast and southwest direction. One of these, containing water and gas, might lie between two anticlinals scarcely affected by either; in which case, according to the anticlinal theory, the elevated northeastern end should be good gas territory, although it might lie exactly in a syncline. Another bed might tend down from the unwarped regions at the north, and have its southerly end uplifted by an anticlinal. Say it is ten miles long; nine miles on the monoclinal slope carries it down about 200 feet, and if it rises 100 feet in the next mile to the crown of the anticlinal, it is there level with a point in the same stratum four and a half miles from its northerly end; and should the sand bed contain a little more water than gas, or its southerly end have less storage capacity than its northerly end, the sand on the anticlinal would be as completely water-logged as in the synclinal north of it. Carrying the illustration still farther, if another sand rock at a higher or lower geological level commences under this anticlinal and extends southwardly, it should be gas-bearing not only on the anticlinal but also in the syncline toward the south, unless it has but little length or is unlifted by another anticlinal a short distance south.

"The effects produced by an anticlinal are further modified, no doubt, by the partial or complete porosity of the sand beds, the relative proportions and qualities of the fluids contained in them, and the different degrees of pressure under which they are confined.

"These may be called fanciful suppositions, but they are neither impossible nor improbable; and knowing that such heterogeneous physical conditions may exist, we should be warned that no theory based on *one idea*, however plausible it may appear, is worthy of acceptance. Yet locators with such theories are most in popular favor, even with many who very well know (if they would but pause to consider) that no man in any age, whatever his pretensions may have been, ever discovered an infallible rule for unerringly locating ore beds or oil and gas wells. And we may confidently add that the diversified conditions under which all minerals exist make it absolutely certain that no such rule ever will be discovered. The oil regions are strewn with financial wrecks caused by an overweening confidence in one-idea theories delusively formulated upon accidental successes and often having no foundation whatever in fact."

Prof. J. P. Lesley, State Geologist, in an address delivered in Pittsburg before the American Institute of Mining Engineers, February 17 last, in referring to the *anticlinal theory*, says:

"Quite recently the location of the anticlinal lines in the Pittsburg region has become a sort of popular mania, produced by a theory. The whole community interested in the subject of natural gas has been carried away by a theory. Practical men and theorists have apparently changed sides; the so-called theorists maintaining a conservative attitude, the so-called practical men becoming wild theorists. And the theory to which I allude is the anticlinal theory of gas.

"Stated in a few words, it is a theory that oil, being lighter than water, must rise to higher levels. If the application of this theory was confined to bottles, no one would dispute it; the water in a bottle must collect at the bottom, the oil in the middle, and the gas on top. But the earth is not a bottle. It has no great caverns in it. More than that, the arrangement takes place naturally under the pressure of only one atmosphere; while any arrangement of water, gas, and oil made at depths of a thousand or two thousand feet must be made under a pressure of from 100 to 500 pounds to the square inch."

"Mr. Carll recites a case where gas escapes at a pressure of 500 pounds to the square inch. It is impossible, therefore, that any arrangement of water, oil, and gas can occur in the deep oil rocks, such as occurs in a bottle. If the anticlinals at Pittsburg were like those in Middle Pennsylvania, where the rocks instead of lying nearly flat are turned up nearly vertical, the water, oil, and gas at great depths, if they could exist at all, would remain practically mixed like the carbonic acid gas in a soda water fountain. It therefore seems to me irrational to assign any importance whatever to the extremely gentle anticlinals of the gas-oil region.

"To this I add the important consideration that the movements of oil and water have been shown by actual practice to be governed entirely by the character of the rock in which they take place, and that they are effectually stopped at fixed geographical lines where porous rock changes into sandstones and sandstones into shales. And these changes of character in the rock itself have no fixed relation whatever to the anticlinal waves, which on the contrary cross them transversely or diagonally.

"Finally, sufficient instances can be adduced to refute the popular assertion that great gas wells are struck *only* on anticlinal lines; for some of them deliver gas from the bottom of basins. And on the other hand, holes sunk on well-known anticlinal lines, and not far from good gas wells, have yielded little or no gas at all.

"As this whole subject is dealt with by Mr. Carll in his forthcoming report, I will say no more."

4 and 5. The relative proportion of water, oil, and gas in a sand bed, and the pressure * under which the gas exists, have an important bearing upon its occurrence, when considered in conjunction with the dip of the sand and the position of anticlines. If nothing but gas existed in a given homogeneous sand bed, having only the ordinary dip of the strata in the oil region, from which the gas could not escape by cracks into overlying strata, and the quantity of confined gas being such that it should fill all portions of the rock with gas under a great pressure, it must be apparent that no matter where the gas sand was pierced by a well, the same quantity of gas would be obtained, excepting so far as it might be influenced by the force of gravity. If petroleum, water, and gas should all exist in the same sand bed, the pressure on each would necessarily be approximately † the same, if there was an open connection throughout the whole extent of the rock in which they occurred; but the water would seek the lowest level of the sand bed, the oil the next, and the gas would be found in the highest portions. The same condition of affairs would exist where either water or oil existed in the sand with the gas to the exclusion of the other.

A careful study of these facts makes it apparent that under special conditions the anticlinal theory alone may account for the existence of gas; but when, however, it is known that large gas wells have been found in synclines, under conditions differing from those which obtain in the vicinity of gas wells on anticlines, it is quite certain that the occurrence of natural gas in the Pennsylvania and New York regions cannot be explained but by a careful consideration of *all* the geological and physical conditions under which it is procured.

Although the horizontal structure of the oil and gas regions is comparatively simple, the columnar structure, as revealed both by the study of the outcropping rocks and the records and drillings of oil wells, is not so easily understood, and in special areas is more or less complex. The rocks which have so far been found to produce natural gas are found in a vertical range of about 3,000 feet of Carboniferous and Devonian strata, extending from the Mahoning sandstone at the base of the Lower Barren coal measures, which is on an average about 500 feet below the Pittsburg coal bed, down to the Smethport oil sand in McKean county, which is 360 feet below the great Bradford oil sand of that region. The principal gas horizons are (*a*) the probable representative of the Venango first oil sand at Pittsburg, which is from 1,800 to 1,850 feet below the Pittsburg coal bed, and contained, as I believe, in the Catskill formation No. IX.; (*b*) the Sheffield gas sand, which appears to be the lowest oil and gas sand in Warren county—the horizon of this sand is about 800 feet above the bottom of the interval of 3,000 feet; and (*c*) the Bradford oil sand, which occurs 1,775 ft. below the base of the Pottsville conglomerate, which is the lowest member of the Lower Productive coal measures. The Sheffield and Bradford sands are undoubtedly of Chemung age.

While most of the largest gas wells which have been drilled in Pennsylvania have obtained gas from these three horizons, yet gas in commercial quantities is not exclusively confined to them. Between the Mahoning sandstone as the top limit and the Smethport oil sand as the bottom limit, about ten (more or less) prominent sand beds have been found which produce petroleum, and each one of these sand beds has been found to contain gas in greater or less quantity, nor is it possible to say that the gas is confined exclusively to these definite sand horizons, for sand beds having only a local occurrence, but included within the rock interval of 3,000 feet, may contain gas.

Prof. Lesley, in speaking of the durability of our natural gas supply, says:

"I take this opportunity to express my opinion in the strongest terms, that the amazing exhibition of oil and gas which has characterized the last twenty years, and will probably characterize the next ten or twenty years, is nevertheless, not only geologically, but historically, a temporary and vanishing phenomenon—one which young men will live to see come to its natural end. And this opinion I do not entertain in any loose or unreasonable form; it is the result of both an active and a thoughtful acquaintance with the subject. From the time that Colonel Drake sank the first well on the plains of Titusville I have professionally participated in the history of the oil and gas developments, and believe myself to be familiar with whatever has been said and done in the premises; and there does not remain upon my mind a shadow of doubt respecting the practical extinction, in the comparatively near future, of that great commerce in oil of which the people of Pennsylvania have foolishly taken so little advantage, when they might have accumulated from its sale in all quarters of the world a provision of moneyed wealth unheard of in the history of our race. The opportunity is indeed still offered; but it is steadily diminishing, and in a few years it will entirely pass away, never to return again. For I am no geologist if it be true that the manufacture of oil in the laboratory of nature is still going on at the hundredth or the thousandth part of the rate of its exhaustion. And the science of geology may as well be abandoned as a guide if events prove that such a production of oil in Western Pennsylvania as our statistics exhibit can continue for successive generations. It cannot be; there is a limited amount. Our children will merely, and with difficulty, drain the dregs.

"I hold the same opinion respecting gas, and for the same reasons; with the difference merely that the end will certainly come sooner, and be all the more hastened by the multiplication of the gas wells, and of the fire-boxes and furnaces to which it is led."

* The pressure under which the gas flows from different wells varies greatly. In the Pittsburg district it ranges on an average between 100 and 200 pounds per square inch. Mr. Carnegie reports that at their works, where the gas is used nine miles from the well, the pressure was 75 lb. per square inch. When I visited the Bessemer Steel Co.'s works, at Homestead, on the 27th of last August, the recorded pressure was 60 lb. per square inch. Mr. W. S. Jarboe has recently reported to me a pressure of 650 lb. per square inch obtained at a certain well when the gas was confined.

† The pressure at the bottom of a sheet of water or oil which nowhere, in the sand bed, could be of any very considerable height, would be but slightly augmented by gravity.

"I will add two opinions of my own, leaving them to stand for what they are worth:

"1. As gas is a direct product of petroleum by spontaneous evaporation, the life of the gas production will be limited by the amount of the volatile elements held in a definitely limited quantity of petroleum existing underground; and therefore those who are producing and using this enormously valuable mineral substance should take every precaution to prevent its waste, seeing that it is bound to come to an end.

"2. I have for a long time looked upon the extension of the Butler oil belt in a general southwest direction through Washington and Greene counties and into Virginia as probable, and I believe now more confidently than ever, since the drilling of the Washington district wells, that a considerable addition to our oil and gas wealth will be made in future years by a series of oil and gas strikes at greater depths in that direction. But thus far facts all point to a greater production of gas than of oil from that region."—*American Manufacturer.*

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